NAVSHIPS 0901-622-0002

September 1968 Edition

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NAVAL SHIPS TECHNICAL MANUAL

CHAPTER 9622

PORTABLE STORAGE BATTERIES AND DRY BATTERIES

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NAVAL SHIP SYSTEMS COMMAND, WASHINGTON, D. C. 20360

NAVAL SHIPS TECHNICAL MANUAL

CHAPTER 9622—PORTABLE STORAGE BATTERIES AND DRY BATTERIES

September 1968 Edition

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Part 1. Definitions and Characteristics (lead-acid type)

9622.1 DEFINITIONS

1. **Cell.** A storage battery cell is a unit consisting of positive and negative plates, separators, cell covers, and electrolyte, properly assembled in a single jar, or one compartment of a monobloc case. (Figure 9622-1 a, d, e, f, i).

2. **Tray.** A tray consists of one or more cells assembled in a common container or a monobloc case. (Figure 9622-1 b, c).

3. **Battery.** A battery may consist of one cell, one tray of cells, or a number of trays of cells connected in series, parallel, or series—parallel.

4. **Positive Group.** This consists of all the positive plates of a cell, the positive plate lugs being lead burned to a common carrier known as a plate **strap.** Rising from the strap, and an intergral part of it is the **positive terminal post,** which protrudes through the top of the cell cover.

5. **Negative Group.** This consists of all the negative plates of a cell, the negative plate **lugs** being lead burned to a common carrier known as a plate **strap.** Rising from the strap, and an intergral part of it, is the **negative terminal post,** which protrudes through the top of the cell cover.

6. **Separators** are spacers placed between positive and negative plates to prevent short circuiting between plates of opposite polarity. They may be made of wood, or microporous rubber, either ribbed or nonribbed. Where grooved separators are used, the flat surface is placed next to the negative plate. (Figure 9622-1 d, e, f, i).

7. **Retainers** are sheets of suitable material used in conjunction with the separators to aid in holding the active material of the positive plates in place and to protect the separator from the action of the positive material. They measurably increase the life of a battery. These sheets may be made of hard rubber or synthetic compounds properly perforated slotted to permit free flow of electrolyte (Military Specification MIL-S-2788). They also may be made of fibrous glass mats, the fibers being held in place by a soluble or insoluble binder. The assembly of retainers, plates, and separators may take any one of the following arrangements:

a. Positive plate, slotted or perforated retainer, separator, negative plate.

b. Positive plate, glass mat, slotted or perforated retainer, separator, negative plate.

c. Positive plate, glass mat, separator, negative plate. Retainers add to the internal resistance of the battery and, therefore, reduce the capacity at high rate discharges. Accordingly, retainers are not always used, being omitted especially from certain batteries designed for high discharge rates and relatively short life. (Figure 9622-1 d, e, f, i).

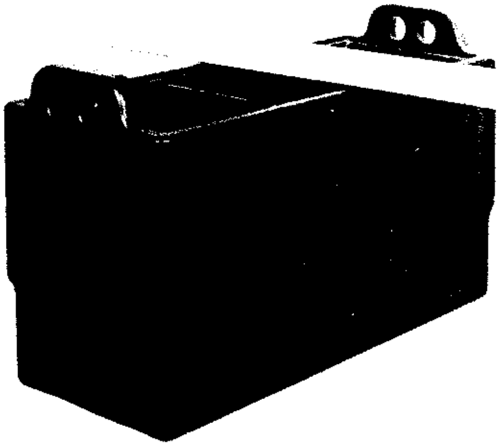


Figure 9622-1 (a). Typical 3-cell hard rubber case for a lead acid portable storage battery.

8. **Element.** An element is the assembly of a positive group and a negative group with separators and retainers as necessary in place. Elements as furnished for replacement in Navy portable storage batteries include the cell cover, sealing nuts with gaskets, and vent plug with gasket. (Figure 9622-1 i).

9. **Electrolyte** is the mixture of sulphuric acid, H_2SO_4, and pure distilled water which is placed in the cell.

10. **Jar.** A jar is a container of suitable material in which a single cell is assembled.

11. **Monobloc case.** This is a case in which a number of individual cell jars are molded in one piece. (Figure 9622-1 a, i).

12. **Cell cover** is the cover, made of suitable material, fitted and sealed in place in the top of the jar or cell compartment of a monobloc case. There are holes in the cover through which the terminal posts of the elements are passed and sealed in place. There is also an opening provided for watering the cell and for taking specific gravity and temperature readings. This opening is threaded in a suitable manner to receive the vent plug. In a few special assemblies there may be a separate opening for venting gases. (Figure 9622-6 g, i).

13. **Vent plug** is a suitable threaded plug with a vent hole and baffles so arranged that when in place it will

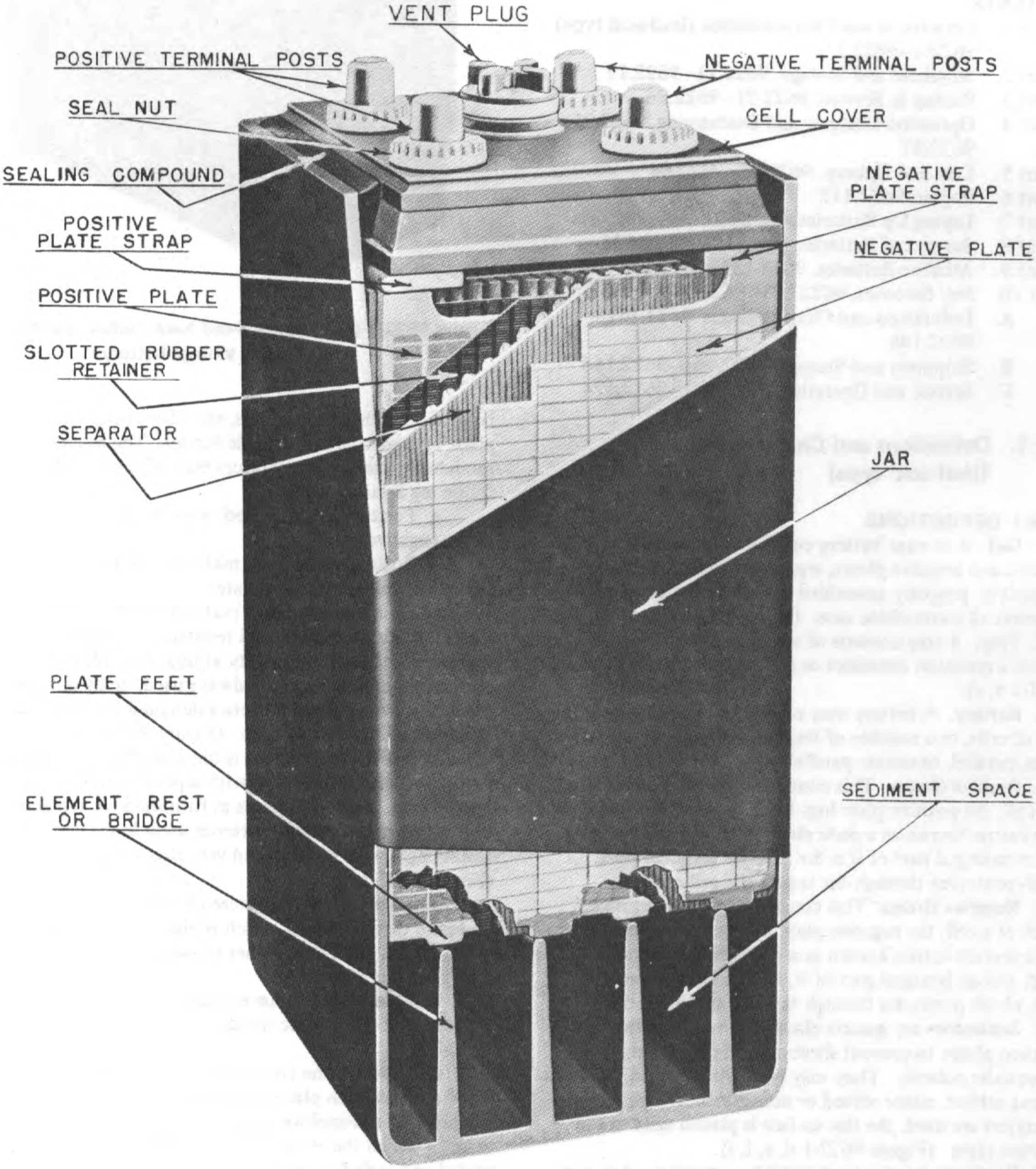


Figure 9622-1 (b). Cut away cell showing slotted rubber retainers.

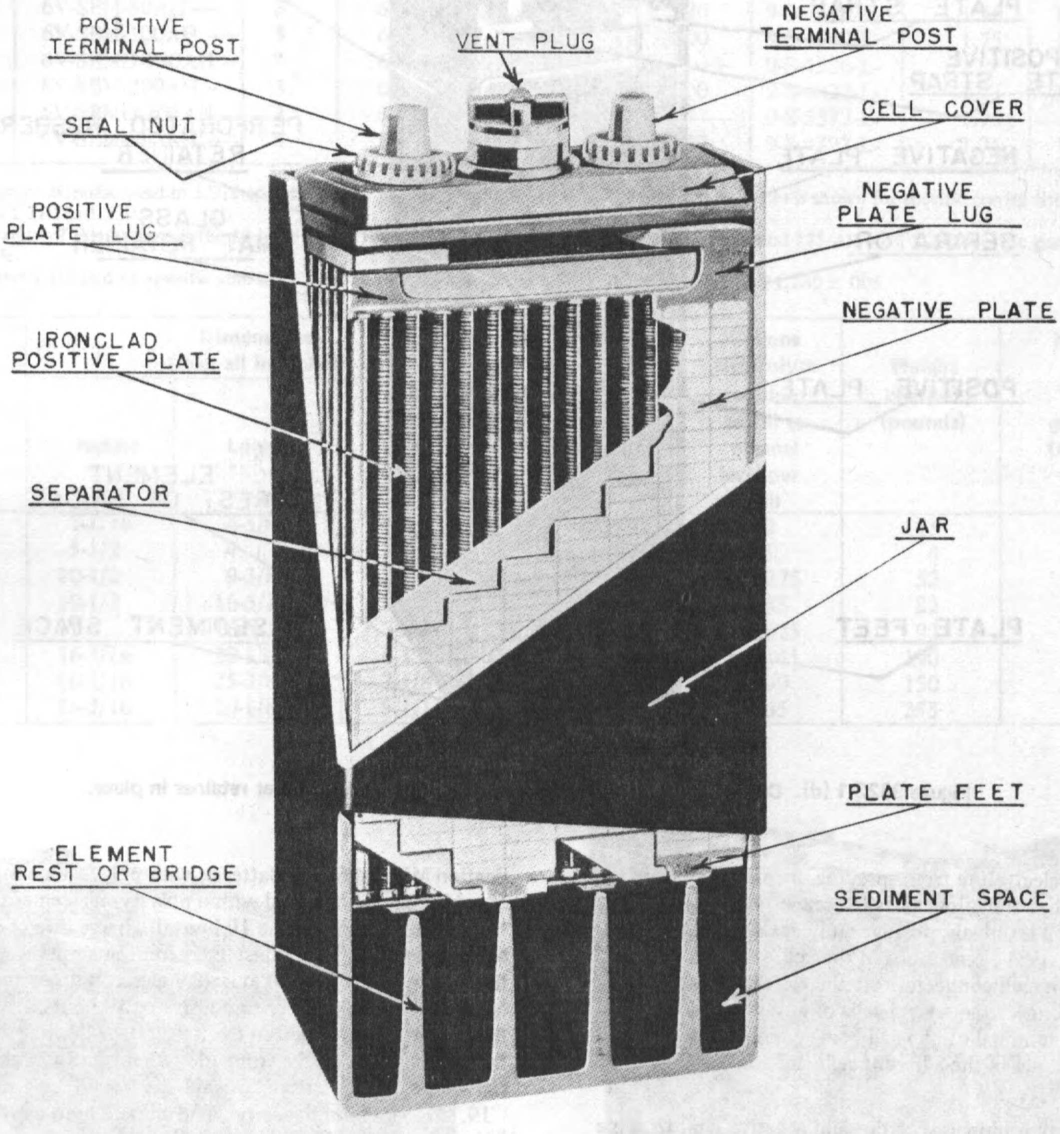


Figure 9622-1 (c). Cut away cell showing Ironclad positive plate.

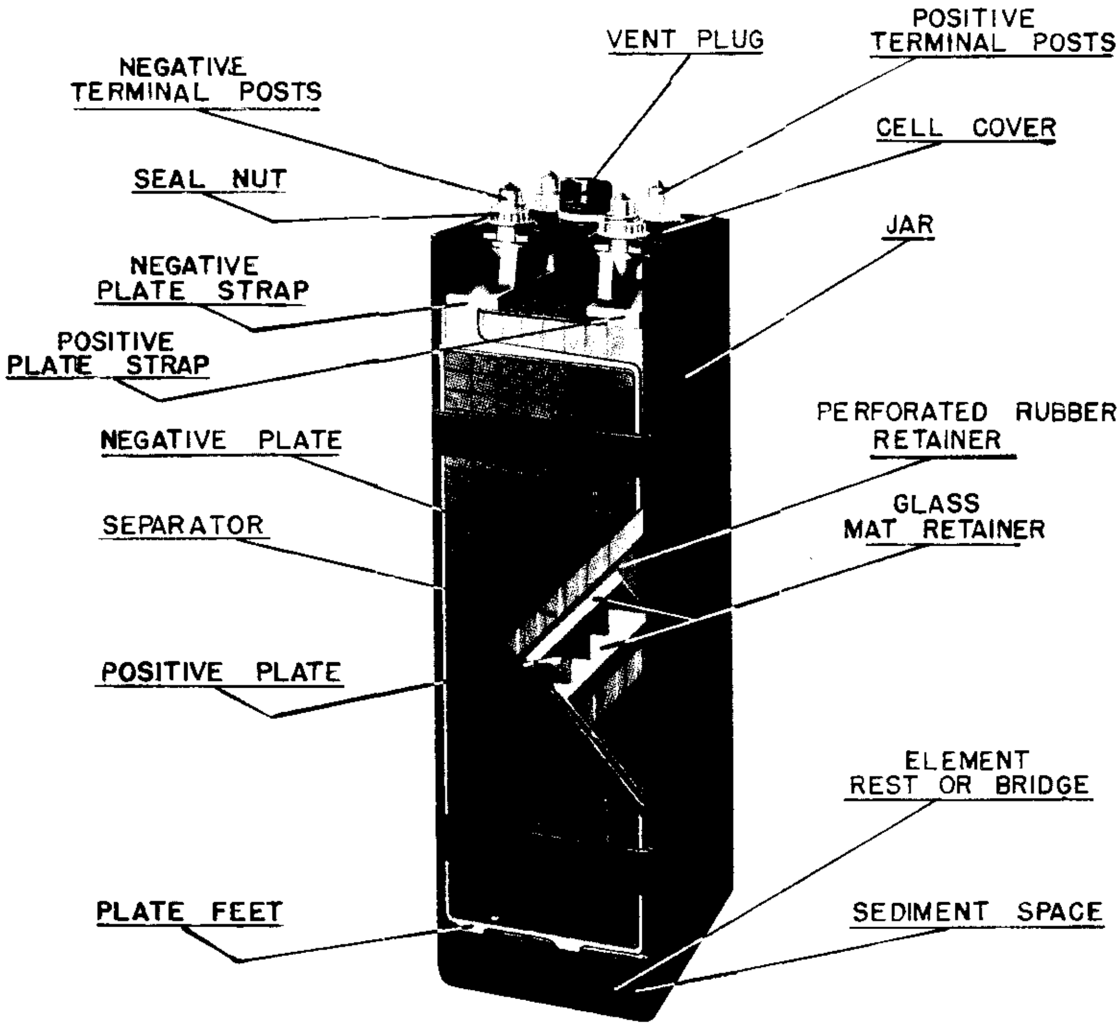


Figure 9622-1 (d). Cut away cell showing glass mat and perforated rubber retainer in place.

prevent electrolyte from spraying or splashing out of the cell but still allow gases to escape. (Figure 9620-6 h).

14. **Cell terminals**, positive and negative, are the outside electrical connections of the cell.

15. **Intercell connectors** are the electrical conductors which connect the several cells of a tray in series, the positive terminal of one cell being connected to the negative terminal of the adjacent cell, and so on. (Figure 9622-1 b, c, i).

16. **Tray terminals**, Positive and negative, and in some types a center terminal, are the outside electrical connections of the tray. In two-terminal type the positive is painted red and mark (+) or "POS," the negative, black and marked (-) or "NEG." The three-terminal type is marked "P" or "POS," "24-Volt," and "N" or "NEG." (Figure 9622-1 j).

17. **Sealing compound** is an asphaltic bituminous compound used to seal the cell cover to the case so that there will be no loss of electrolyte at this point (Military Specification MIL-C-2687). Batteries with polystyrene instead of rubber parts are sealed with a polystyrene cement.

18 **Discharge rate.** The **10 hour discharge** rate of a battery is equal to the constant current in amperes which the battery, starting with an initial electrolyte temperature of 80° F., can supply continuously for 10 hours before the voltage has dropped to the low voltage limit at which the discharge should be stopped. Other hourly discharge rates are defined in a similar way.

19. **Ampere hour capacity.** The ampere hour capacity of a battery at a specified constant discharge rate in amperes is the number of ampere hours the battery will deliver at that rate before the voltage drops below a specified limiting voltage. The ampere hour capacity of a battery depends upon the rate of discharge and is greater when the battery is discharged slowly than when it is discharged rapidly.

9622.2 CHARACTERISTICS

Following is a summary of the characteristics, dimensions, and weight of Navy portable storage batteries:

Type	Former Navy Class	Cells per tray	Volts per tray	Capacity at ten-hour rate in ampere hours	5-minute rate in amperes	Bureau Standard Drawing	Low-voltage limit per cell	
							10-hour rate	5-minute rate
BB255	6V-SBM-15AH	3	6	15	—	9-S-5390-L-	1.75	—
BB254	2V-SBP-20AH[1]	1	2	[1] 20	—	9-S-5408-L-	1.75	—
BB252	6V-SBM-50AH	3	6	50	120	9-S-4696-L-	1.75	1.20
BB256	6V-SBM-100AH	3	6	100	300	9-S-4652-L-	1.75	1.20
BB257	6V-SBMD-130AH	3	6	[2] 130	—	9-S-4906-L-	175	1.20
BB258	6V-SBM-200AH	3	6	200	500	9-S-4822-L-	1.75	1.20
BB253	6V-SBMD-205AH	3	6	205	—	9-S-5372-L-	1.75	—
BB259	6V-SBM-300AH	3	6	300	720	9-S-4823-L-	1.75	1.20

[1] This battery manufactured in 1.275 specific gravity electrolyte only. Capacity for all other batteries is shown for specific gravity within the limits 1.210 to 1.220.

[2] The capacity of this battery at the 10-hour rate is 130 AH with 1.215 specific gravity electrolyte and 175 AH with 1.280 specific gravity electrolyte.

[3] The capacity is based on specific gravity of 1.215 ± .005. Tests will be based on specific gravity of 1.280 ± .005.

Type	Dimensions (over all in inches)			Number of plate per cell	Gallons electrolyte required to fill to normal level per cell	Weight charged (pounds)	Manufacturer's life guarantee (minimum cycles)
	Height	Length	Width				
BB255	7-1/16	4-5/8	4-3/4	5	.2	15	600
BB254	5-1/2	4	3	11	.1	4	150
BB252	10-1/2	9-3/8	7-1/8	7	.275	52	500
BB256	10-1/2	16-5/16	7-1/8	17	.55	82	500
BB257	11	16-5/16	7-1/8	27,29	.625	92	150
BB258	16-3/16	20-13/16	6-13/16	15	1.141	190	600
BB253	10-7/16	25-3/8	7-1/8	41	.99	150	150
BB259	16-3/16	20-1/8	9-1/16	21	1.65	255	600

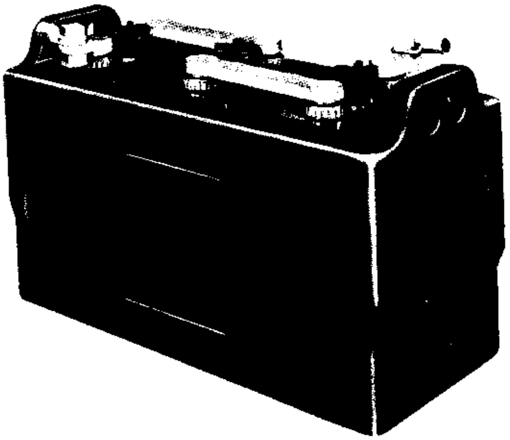


Figure 9622-6 (e).

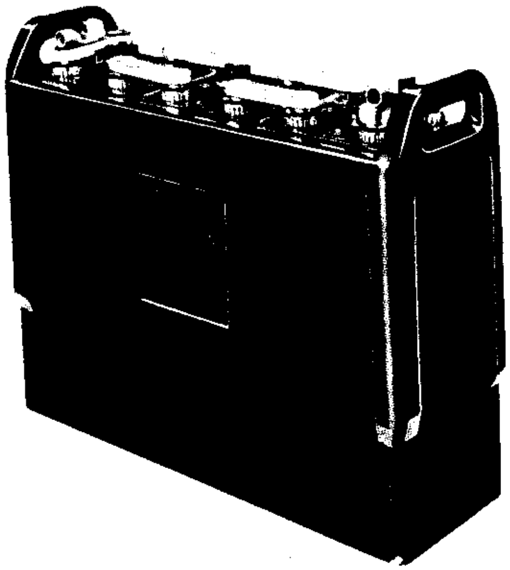


Figure 9622-6 (f). Navy portable storage battery, Class 6V SBM 200AH.

Figure 9622-1 (g).

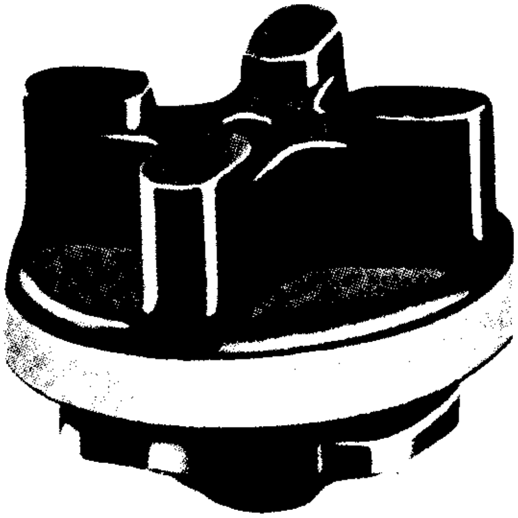


Figure 9622-1(h). Vent plug showing gasket.

9622.3 REACTIONS DURING CHARGE AND DISCHARGE

The exact nature of the chemical reactions which take place in a cell is rather involved, but the following brief description will give some idea of what occurs during a cycle of discharge and charge:

1. When a cell is fully charged (Figure 9622-2 a), the active material of the positive plate is in the form of lead peroxide, PbO_2, and of the negative plate pure sponge lead, Pb. The specific gravity of the electrolyte (sulphuric acid, H_2SO_4, and water, H_2O) is at its maximum. Chemical energy is stored in the cell in this condition.

2. If an external circuit is closed between the positive and negative terminals of a cell current begins to flow due to the action of the electrolyte upon the active material. The chemical energy thus is transformed into electrical energy, and the cell is said to be discharging (Figure 9622-2 b). The electrolyte reacts with the active material to form lead sulphate on both the positive and negative plates. As the discharge progresses, the acid content of the electrolyte becomes less and less as it is used in forming lead sulphate, and the specific gravity of the electrolyte as read by the hydrometer therefore decreases. A point is reached where so much of the active material has been converted into lead sulphate that the cell can no longer produce sufficient current (electrical energy) to be of practical value and at this point the cell is said to be discharged. (Figure 9622-2 (c).) Since the amount of sulphuric acid combining with the plate at any time discharge is in direct

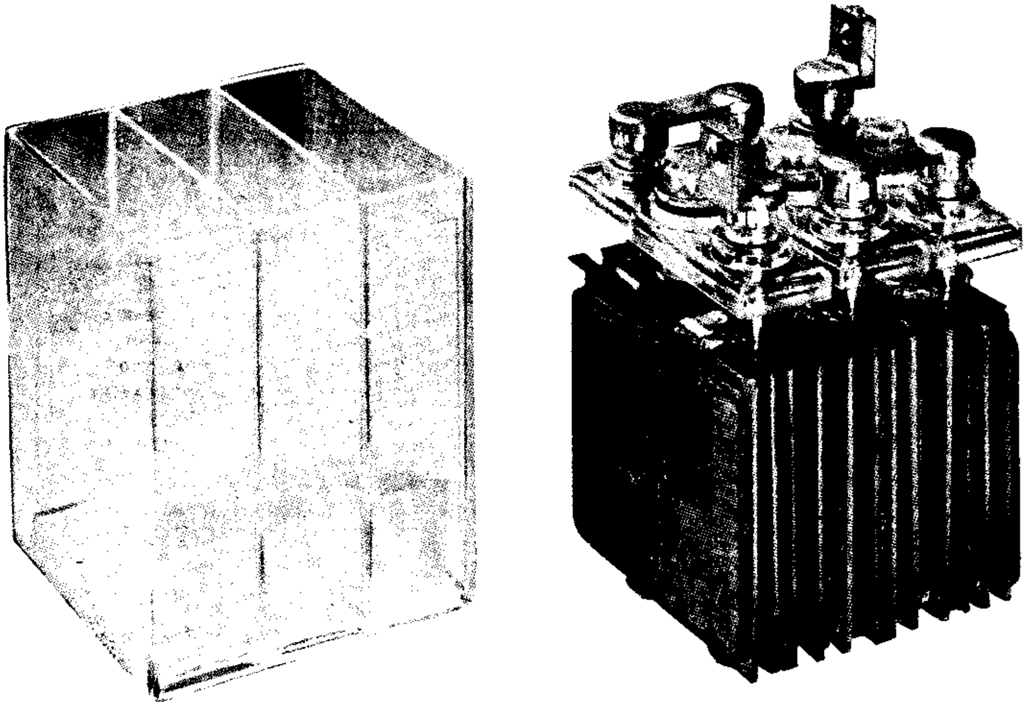


Figure 9622-1 (i). Navy portable storage battery. Class 6V SBM 15AH, showing elements and cell covers ready for installation in polystyrene case.

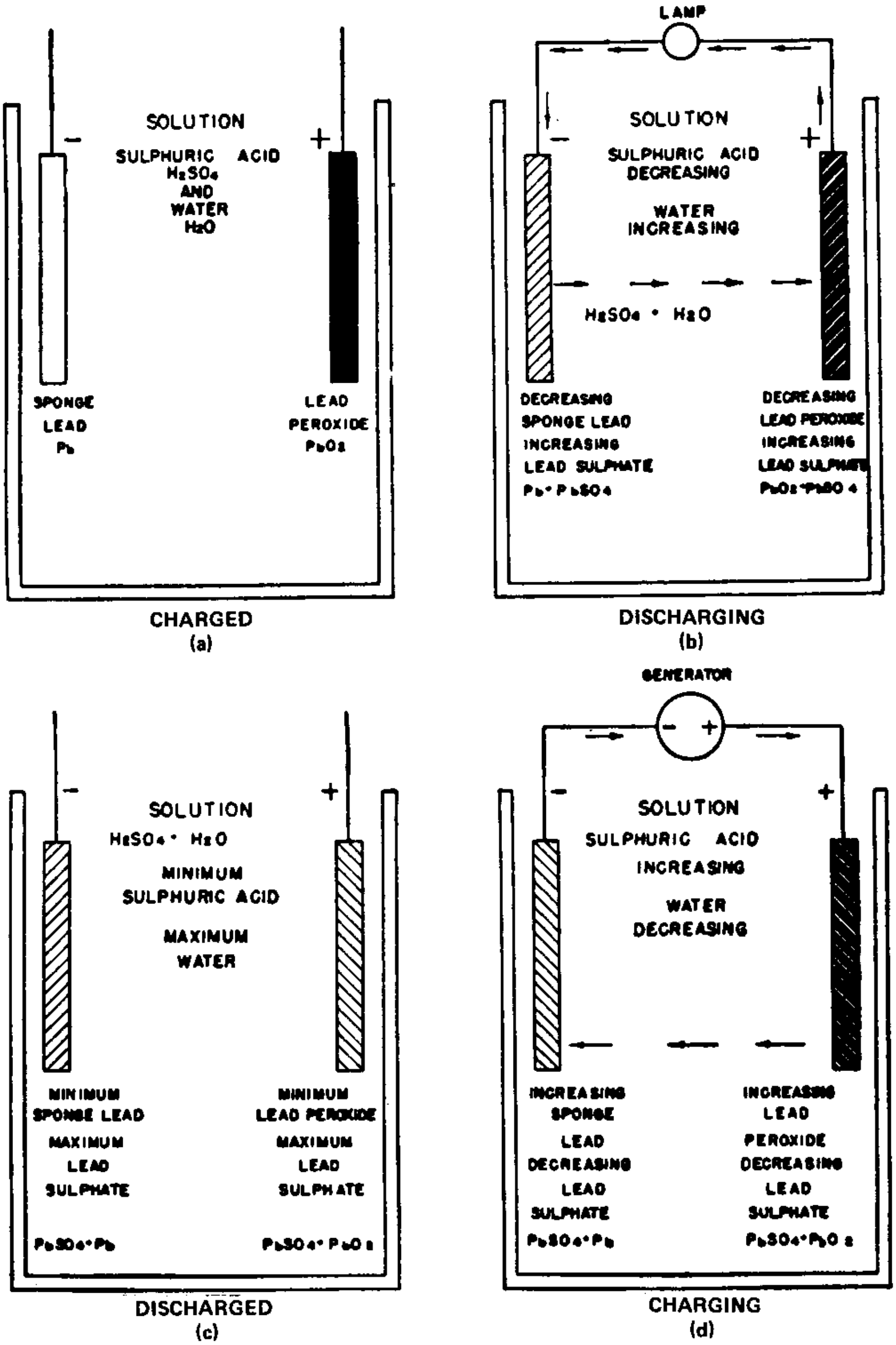


Figure 9622-2 (a), (b), (c), and (d). Chemical reactions during charge and discharge.

proportion to the ampere hours of discharge, hydrometer readings can be used as a guide in determining the state of discharge of a lead-acid cell.

3. If the discharged cell is properly connected to a direct current charging source, of voltage slightly higher than that of the cell, current will flow through the cell in the opposite direction to that of discharge and the cell is said to be charging (Fig. 9622-2 d). The effect of the current will be to change the lead sulphate on both the positive and negative plates back to its original active form of lead peroxide and

sponge lead, respectively. At the same time, the sulphate is restored to the electrolyte with the result that the specific gravity of the electrolyte increases. When all the sulphate has been restored to the electolyte, the specific gravity will be a maximum. The cell is then fully charged, and is ready to be discharged again. It is always to be remembered that the addition od sulphuric acid to a discharged storage battery **does not recharge the battery**. Adding acid increases the specific gravity of the electrolyte but it does not convert the lead sulphate on the plates back into active material, sponge lead and lead peroxide, and consequently does not bring the battery back to a charged condition. A charging current must be passed through the battery to do this.

4. The combined reactions during charge and discharge may be represented by the relation:

$$Pb + PbO_2 + 2H_2SO_4 \underset{\text{Charging}}{\overset{\text{Discharging}}{\rightleftarrows}} 2PbSO_4 + 2H_2O$$

5. In addition to the above reactions, as a battery charge nears completion, hydrogen gas, H_2, is liberated at the negative plate, and oxgen gas, O_2, at the positive plate. This is becaused the charging current is greater than is necessary to reduce the small remaining amount of lead sulphate on the plates, and the excess current applies itself to the electrolysis of the water in the electrolyte. This is necessary to assure full charge to the battery.

Part 2. Shipment and Storage

9622.11 FACTORY INSPECTION OF STORAGE BATTERY

All material entering into the construction of a storge battery is carefully inspected by Naval Inspectors to insure that the batteries shipped from the factory conform with Navy Specifications.

9622.12 CONDITION OF BATTERIES ON SHIPMENT

1. Batteries are shipped in one of the following conditions:
    a. Filled and charged.
    b. Dry and uncharged.
    c. Dry and charged.
2. When shipped filled and charged, the cells are completely assembled, contain electrolyte, are sealed, fully charged, and ready for use.
3. When shipped dry, the battery is assembled and sealed, with separators in place, but contains no electrolyte. The plates are in the uncharged condition. Such batteries require filling and an initial charge to place them in commission.
4. When shipped dry and charged, the battery is assembled and sealed, with separators in place, but contains no electrolyte. The plates are in the charged condition. To put such batteries in service, it is necessary only to fill them with electrolyte in accordance with the manufacturer's instructions attached to the battery.

9622.13 CARE IN UNPACKING BATTERY

1. If batteries are received in crates or packing boxes, care must be taken in unpacking and handling. Keep the batteries right side up.

2. **Receipt of battery shipped filled and charged.** On the receipt of batteries in the filled and charged condition proceed as follows:

a. Remove vent plugs and examine height of electrolyte. Take specific gravity and temperature readings of all cells to ascertain state of charge.

b. If level of electrolyte is below the bottom of the filling tube, or the level mark on polystyrene cells, and there is no evidence of spilling or other leakage, add sufficient distilled water to bring the level even with the bottom of the filling tube or mark. Unless otherwise specified, the electrolyte level should be 3/8 inch above the separators.

c. If inspection shows that electrolyte has been spilled during shipmen, replace it with electrolyte of 1.215 specific gravity corrected to 80° F.

d. If loss of electrolyte has been caused by a cracked or broken jar or case, remove the element and immerse it in pure distilled water in a rubber or glass container until a new jar can be provided. Wood or metal containers shall not be used.

d. If water or electrolyte is added, place the battery on charge at the finishing rate until specific gravity readings, corrected for temperature, are constant for a period of five hours.

f. If the battery is not to be put into service immediately, give it an equalizing charge within one month from the date of initial charge stamped on the name plate. Thereafter the battery shall be given an equalizing charge at one month intervals or sooner if the specific gravity has fallen to 1.180, and just before being placed into service.

9622.14 RECEIPT OF BATTERY SHIPPED DRY

1. If a battery is received in the dry-uncharged or dry-charged condition and is not to be placed in service upon receipt, the vent plugs must be kept tightly in place and the battery stored in a clean, dry place until ready for placing in service. A period of about 5 days should be allowed for giving a dry-uncharged battery the initial charge and placing in service. Allow 1 day for dry-charged batteries.
2. When the battery is to be placed in service, follow the instructions on the tag accompanying the battery. This specifies the specific gravity of the electrolyte to be used in filling the cells, the time to allow for soaking of the electrolyte into the plate before charging, temperature limit, method of conducting the initial charge, and other instrutions, depending on whether the battery is dry-charged or dry-uncharged.

9622.15 ELEMENTS

Elements which are shipped as such are packed in a special manner to prevent damage during transit or storage. The package must not be opened until the element is required for use. Each element is completly ready for installation in the cell that is being repaired.

9622.16 GREASE ON TERMINAL BOLT STUDS

Terminal blt studs of all batteries will be found covered with grease. This is used to prevent corrosion around the terminals and must not be removed.

9622.17 STORAGE OF BATTERIES OR PARTS

If batteries, elements, spare plates, separators, jars or covers are to be stored temporarily, put them in a dry clean place where the average temperature is about 75° F. and in no case below 50° F. or above 100° F.

Part 3. Placing in Service

9622.21 MANUFACTURER'S INSTRUCTIONS

1. To each tray when shipped dry the various battery manufacturers attach instructions for placing the battery in service and for giving it the initial charge when required.

2. **Dry-uncharged batteries; inital charge in absence of instructions.** In the event the manufacturer's instructions fot the initial charge are not available, fill the cells with acid of the specific gravity indicated in the table shown.

Type of element and separators	Specific gravity of electrolyte used for filling
Flat plate with microporous rubber separators	1.200
Flat plate with glass mat and microporous rubber separators	1.200
Ironclad positives with microporous rubber separators	1.200

Add the electrolyte until its level is up to the bottom of the filling tubes, or the level mark on polystyrene jars, or where there is no mark, at least 3/8 inch above the separators. Filling with electrolyte will cause the battery to become heated. It may be cooled artificially or allowed to stand at least 12 hours to cool. It shall not stand more than 24 hours after filling before beginning the charge. It will be noted that the level of the electrolyte will drop during this period, owing to its soaking into the plates and separators. Before starting the charge, restore the electrolyte level to that prescribed above by filling with acid of the same specific gravity as used initially.

3. To charge, use three-fourths of the finishing rate of the battery, as obtained from the name plate on the tray. Should the temperature reach 125° F., reduce the charging rate or stop the charge until the battery cools. Continue the charge until the voltage and specific gravity, corrected to 80° F., have remained constant for at least 5 hours. However, in no case shall the number of ampere-hours for the initial charge be less than five times the rated capacity at the 10-hour rate as given on the name plate. If the rate is maintained, this will require approximately 84 hours of charging.

4. **Charged and Dry batteries.** The instructions for charged and dry batteries are similar to those for the uncharged and dry with a few exceptions. When the electrolyte is placed in the cells they will have a 70–80% charge and are available for immediate use in case of emergency. It is preferable to first give the battery a thorough equalizing charge after filling. The charged and dry batteries must be stored in a cool dry location until ready for use, and under these conditions the plates will retain most of their charge for as long as two years. Once the battery has been properly prepared, its capacity, life and characteristics are the same as a new "wet" battery.

9622.22 ADJUSTING SPECIFIC GRAVITY AFTER INITIAL CHARGE OF DRY-UNCHARGED BATTERIES

After completing the initial charge, adjust the specific gravity corrected to 80° F., to that required on the name plate. If mixing of the electrolyte has been carefully done, little adjustment should be necessary. (See art. 9622.112.)

9622.23 DATE OF INITIAL CHARGE TO BE STAMPED ON NAME PLATE

1. **Dry-uncharged batteries.** The date of the initial charge shall be stamped or scribed in the proper place on the name plate of each tray in an easily legible manner. This is important since it gives the date at which useful life of the battery begins.

2. **Dry-charged batteries.** Instead of the date of initial charge, the date on which the battery was filled for activation will be put on the tray as described in article 9620.223 (1).

9622.24 PUTTING A BATTERY IN SERVICE

To put a battery in service, proceed as follows:

1. Arrange the trays so that the positive terminal of one tray will be connected to the negative terminal of the next, throughout the battery.

2. **Determining polarity of battery terminals.** Arrange connections so that the positive of the charging source will connect with the positive of the battery, and the negative of the charging source with the negative of the battery. If the battery terminals or posts are not properly marked, the polarity may be determined by the use of a voltmeter between the terminals. Another way is to hold the terminal leads about one-half inch apart under to which a little salt has been added. Do not allow the leads to touch. Bubbles will collect on the negative wire (see art. 9622.201 (16)).

3. **Cleaning surfaces to be bolted together.** The metal surfaces of the terminals are likely to be covered with a thin film of acid. Unless this neutralized and removed before making connections, there may be trouble from corrosion later. Before making connections all surfaces which are to be bolted together must be cleaned with dilute ammonia or bicarbonate of soda solution and dried. After bolting together, they should be coated with petrolatum (N D. Spec. 14P1) or cup grease (Military Specification MIL-G-15793).

4. **Making connections.** Care must be taken not to allow the ammonia or bicarbonate of soda solution to get into the cells. It is advisable to brighten the contact surfaces with a wire brush or fine sandpaper after neutralizing with ammonia or bicarbonate of soda solution and before applying grease. Apply petrolatum or cup grease to bolt studs and connect the cells or trays by bolting the connectors to the cell terminal, placing the connectors under the head of the bolt, and not under the nut.

5. Bolts should be gone over and tightened several times after the first tightening, to insure good connections.

6. After all connections are completed, check over each one to make sure the polarity is correct and then see that any exposed metal in the connectors is thoroughly protected by petrolatum or cup grease.

7. Clean top and side of batteries by wiping with a cloth dampened with dilute ammonia or bicarbonate of soda so-

lution. If bicarbonate of soda is used, the battery then should be washed thoroughly with pure water.

8. Test for short circuits and ground.

9622.25 NUMBERING BATTERIES

1. To facilitate the keeping of battery records, it is necessary to adopt a systematic method of battery identification. Such identification may best be made by assigning a number to each tray. For example, a vessel which has a total of 100 trays of portable storage batteries for all purposes should number each tray, in order, S62-3 (1), S62-3 (2) and so on to S62-3 (100). In addition, the cells in a tray should be numbered consecutively, beginning at the positive end.

2. The identification number assigned as above should be stenciled in a conspicuous place on the side of the container of each tray in figures of sufficient size to be easily identified.

3. The identification numbers assigned as above should be used habitually in keeping all required records; and, whenever reference to a particular battery is made, the serial numbers of included trays as well as a statement of the purpose for wich the battery is used should be given.

4. When a new tray replaces an old one, it shall be given the number of the old one, and a new log begun.

9622.26 PILOT CELLS

Whenever pilot cell readings are needed, two cells for each battery shall be selected at random for this purpose. To do this, place N small cards marked with numbers 1 to N (where N = number of cells in the battery) in a can, mix them thoroughly, draw two, and make the pilot cell readings on the cells whose numbers are drawn.

Part 4. Operation—Charging and Discharging

9622.31 GENERAL

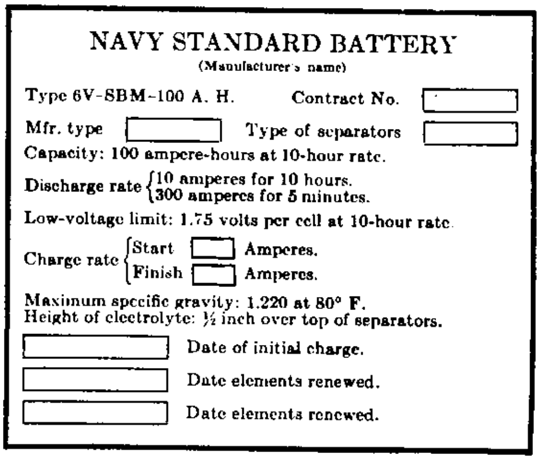
The same careful attention must be given to the operation of a storage battery that is given to the operation of any other power unit. Lack of intelligent supervision in the operation, care, or repair of a battery results in temporary impairment or permanent damage. The instructions contained herein, the manufacturer's instructions, and the data on the name plates of the individual trays must be carefully studied and observed in order that the batteries may be made to perform as designed. A typical name plate is illustrated in figure 9622-8.

9622.32 CHARGING AND DISCHARGING

1. The specific gravity of the electrolyte gradually decreases on discharge, and gradually increases on charge. This decrease and increase is nearly in direct proportion to the number of ampere hours taken out of or put into the battery, and is thus a check upon the state of charge at any time.

2. **Determining state of charge by specific gravity.**

a. Special applications excepted, Navy portable batteries use electrolyte between 1.210 and 1.220 specific gravity. Electrolyte of this low specific gravity is used in order to prolong the life of batteries and at the same time to supply sufficient power fot the intended purposes of the battery. When completly discharged from full charge at the 10-hour rate (the basic rate for purposes of comparison), the specific gravity drops to about 1.060, giving a range of 150 to 160 points. This figure is true of the larger size batteries; in the smaller sizes, however, the drop in specific gravity is less. The number of points drop in specific gravity per ampere hour must be determined for each type of battery. This may be done as follows: For each ampere-hour taken out of a battery a certain definite amount of acid is removed from the electrolyte and combined with the plates. Suppose a battery has been discharged from full charge to the low-voltage limit at the 10-hour rate and 100 ampere-hours obtained with a specific gravity drop of 150 points. Then for each ampere hour obtained there has been a drop of 1.5 points in specific gravity. If 70 ampere hours are taken out of the battery at the ten-hour rate, or at any other rate, or collection of rates, then the drop in specific gravity will be 70 X 1.5 = 105 points.



NAVY STANDARD BATTERY
(Manufacturer's name)
Type 6V-SBM-100 A. H. Contract No.
Mfr. type Type of separators
Capacity: 100 ampere-hours at 10-hour rate.
Discharge rate {10 amperes for 10 hours. / 300 amperes for 5 minutes.
Low-voltage limit: 1.75 volts per cell at 10-hour rate.
Charge rate {Start Amperes. / Finish Amperes.
Maximum specific gravity: 1.220 at 80° F.
Height of electrolyte: ½ inch over top of separators.
Date of initial charge.
Date elements renewed.
Date elements renewed.

Figure 9622-8. Battery name plate.

b. Conversely, if the specific gravity is 1.210 when fully charged and 1.150 after a partial discharge, there has been a drop in gravity of 60 points. This indicates that approximately 60/1.5 = 40 ampere hours have been taken out of the battery. Hence, the number of ampere hours taken out of a battery can be determined from the specific gravity when fully charged, the specific gravity after discharging, and the number of points drop in gravity per ampere hour.

3. **State of charge determined by voltage.** Voltage is not a reliable indication of the state of charge of a battery except when approaching the low-voltage limit on discharge. During a discharge the voltage will vary greatly with the different rates used, the higher the rate the lower the voltage. Unless one thoroughly understands the relation of these variations to the rate of discharge little or no useful information can be obtained as to the state of charge. Open circuit voltage is of little value in finding the state of charge, since the variation between full charge and complete discharge is only about 0.1 volt. Open circuit voltage furnishes an indication of the condition of the battery in that, if internal short-circuits exist its voltage will be lower than normal on open circuit.

9622.33 LOW-VOLTAGE LIMIT

The low-voltage limit is the limit set by the manufacturer as that beyond which very little useful energy can be obtained. In general the low-voltage limits for batteries at different rates of discharge will vary slightly with the size and make of the battery. For Navy portable batteries the low-voltage limits for all sizes are approximately as follows:

Table of low-voltage limits

Rate of discharge	Final volts per cell (low-voltage limit)
3.3 minutes at 0° F	1.00
5 minutes at 80° F	1.20
1 hour at 80° F	1.53
2 hours at 80° F	1.60
3 hours at 80° F	1.65
6 hours at 80° F	1.72
10 hours and over at 80° F	1.75

9622.34 READINGS WHEN CHARGED AND DISCHARGED

At the conclusion of a discharge at the 10-hour rate the voltmeter reading (closed circuit) will be approximately 175 volts per cell and specific gravity approximately 1.060. At the completion of a charge, the voltmeter reading on closed circuit at the finishing rate will be approximately 2.4 to 2.6 volts per cell and the specific gravity 1.210 to 1.220 at 80° F.

9622.35 WHEN TO CHARGE

1. In order to obtain good results from a portable storage battery and to insure long life, proper attention to charging must be given. From the nature of their uses some batteries will require more charging than others. For example, engine starting batteries get moderately heavy use and may require frequent charging in addition to that provided by the engine generator. Conversely, batteries such as are used for auxiliary lighting and power purposes get very little work and need correspondingly less charging.

2. **Limiting specific gravity for stand-by batteries.** Batteries on stand-by service shall be recharge when the specific gravity falls to 1.180, or at least once a month regardless of specific gravity.

3. **Discharge at low voltage limit.** Except in an emergency, discharge must be stopped and batteries charged when the low-voltage limit is reached.

4. **Recharge within 24 hours.** Never allow a battery to stand in a completely discharged condition for more than 24 hours before recharging.

9622.36 CHARGING IN ENCLOSED SPACE

1. Batteries should not be charged in an enclosed space, unless such space is provided with adequate ventilation. See art. 9622.53 of this chapter and also Chapter 9380 for ventilation.

2. Stop the charge if ventilation is interrupted, except in an emergency, and do not resume the charge until ventilation has been restored.

9622.37 TOO FREQUENT CHARGING INADVISABLE

Too frequent charging is to be avoided. The practice of charging batteries when the specific gravity drops only a few points causes batteries to be charged always within the gassing range, which is detrimental to the battery. A battery at 1.200 specific gravity is almost completely charged. Therefore, charging at this time is a waste of energy. Ample reserve power for ordinary operation, without too frequent charging, is the ideal condition.

9622.38 HEIGHT OF ELECTROLYTE BEFORE CHARGING

1. Before starting a charge, see that the electrolyte is at the proper level, adding water if necessary. (See art. 9622.66.) The proper height is just at the bottom of the filling tube, or the level mark on polystyrene jars. However, if not specified, the level should be 3/8 inch above the separators. If the electrolyte is too high, it will run out of the filling tubes during the charge. This is due to the expansion which takes place inside the cell as the temerature rises, and to gassing.

2. **Low-level electrolyte.** If the electrolyte is at the correct height above the plates, the heat transfer to the metal straps and risers is much greater than if the plates are barely covered. Consequently, the temperature rise during charge and discharge will be less for a properly filled cell than for a cell in which the level is low. If electrolyte gets too far below the top of the plates or separators and remains there, the exposed parts of the plates will harden and the separators will become dry. This will cause reduction in capacity and shorten the life of the battery.

9622.39 VOLTAGE OF CHARGING LINE

In order to charge a battery it is necessary that the voltage of the charging line exceed the total voltage of the batteries connected in series and being charged. In other words, the total number of cells to be charged shall not exceed the voltage of the charging line divided by 2.6.

9622.40 CONNECTING BATTERIES IN SERIES

When charging more than one tray at a time in series, connect the (+), or positive terminal of one tray to the (-), or negative terminal of the next, regardless of the number of trays connected. This leave one positive and one negative terminal to be connected to the corresponding terminals of the charging circuit (Fig. 9622-9).

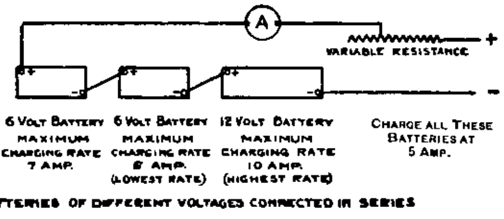


Figure 9622-9. Batteries of different sizes connected in series.

9622.41 CHARGING SEVERAL BATTERIES IN SERIES AT ONE TIME

If the batteries are of different sizes, the charging rate, in amperes, must not exceed the maximum charging rate of any one battery in the line (Fig. 9622-9).

9622.42 USE OF LAMP BANK

1. When a lamp bank instead of a rheostat is used to regulate the current, the rate in amperes is increased by turning lamps into their sockets and decreased by turning out. The amperes of current that pass through one light can be computed by dividing watts by volts. For example, a light bulb marked "110 volts, 100 watts," requires

$$\frac{100}{100} = .91 \text{ amperes at 110 volts}$$

2. The computation shown above is true when the voltage across each light is 110 volts, but when charging a battery, the counter E. M. F. and IR drop of the battery cause the voltage across the lights to be less than 110 volts. The following table is a guide to show the number of lights in parallel required to charge various numbers of cells in series, using Navy standard incandescent lamps and voltage from 110 to 120 volts direct current:

Number of cells in series	Rating in watts of lamps connected in parallel								
	2 amps	4 amps	7 amps	8 amps	14 amps	16 amps	22 amps	32 amps	44 amps
3--------------	239	478	838	955	1,675	1,910	2,625	3,810	5,250
6--------------	249	498	870	995	1,741	1,987	2,739	3,980	5,470
9--------------	259	518	906	1,036	1,812	2,072	2,845	4,130	5,697
12-------------	272	543	950	1,086	1,901	2,171	2,985	4,340	5,967
15-------------	285	570	999	1,140	1,997	2,282	3,140	4,570	6,272
21-------------	320	639	1,119	1,278	2,239	2,556	3,520	5,110	7,032
27-------------	366	732	1,280	1,464	2,560	2,829	4,025	5,850	8,055
30-------------	398	795	1,391	1,590	2,782	3,180	4,370	6,360	8,750
33-------------	447	897	1,565	1,798	3,130	3,595	4,920	7,150	9,830

3. The above figures give the total rated watts of lamps connected in parallel, and take into account the variation in the resistance of the filament of lamps at various voltages and temperatures. The figures can be rounded out to the nearest 100 watts if desired. For example, to charge three trays (nine cells) of type 6V-SBM-50AH batteries in series at approximately the 8-ampere starting rate, it would be necessary to use ten 100-watt lamps, or forty-one 25-watt lamps, connected in parallel. (Figure 9622-10.) The voltage across the nine cells connected is series would be approximately 22.5 volts, and across the lamps about 92.5.

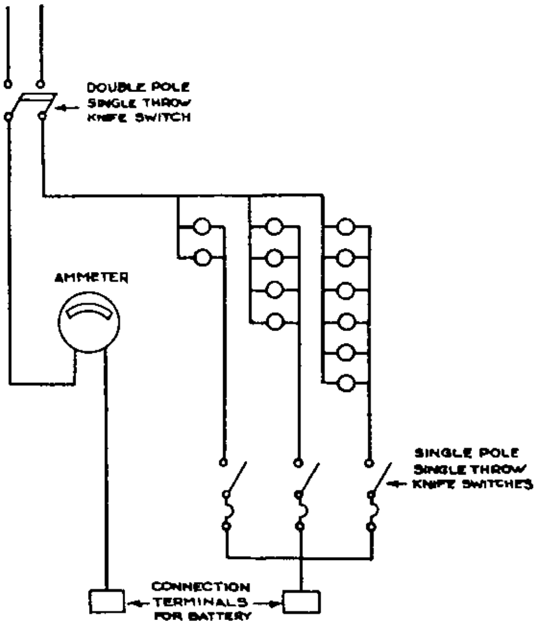


Figure 9622-10. Method of connecting lamp bank for charging.

9622.43 KINDS OF CHARGES

The following types of charges may be given to a battery.

1. **Initial charge.** A long, low rate, forming charge which is given to place new plates in service. Dry-charged batteries do not require initial charges. (See arts, 9622.21 to 9622.23, incl.)

2. **Normal charge.** A routine charge given in accordance with the data on the name plate during ordinary cyclic operation to restore the battery to a substantially fully charged condition. (See art. 9622.44).

3. **Equalizing charge.** An extended charge at the finishing rate, given periodically to insure that all the sulphate is driven from the plates and that all cells are restored to a uniform maximum gravity. (See arts. 9622.45 and 9622.46).

4. **Floating charge.** A battery may be maintained at full charge by floating it across a power line that has a voltage which is maintained within the limits of 2.13 to 2.17 volts per cell in the battery (see art. 9622.47).

5. **Emergency charge.** This charge is one that usually starts at a much higher rate than is normally used for charging and is designed to give the battery the maximum charge possible in the shortest period of time (see art. 9622.48)..

9622.44 STEPS IN GIVING A PORTABLE STORAGE BATTERY A NORMAL CHARGE

To give a portable storage battery a normal charge proceed as follows:

1. Ascertain the proper charging rates to be used for starting and finishing the charge. Charging rates approximately equal to those given on the battery name plate are preferable but are not always obtainable with the charging equipment available. In such cases, charging rates which are greater than those given on the battery name plate but less than or equal to those given in the following table are satisfactory:

Type	Former Navy Class	Charging rates in amperes	
		Start	Finish
BB254	2V-SBP-20AH	2	1
BB255	6V-SBM-15AH	1.5	1
BB252	6V-SBM-50AH	8	4
BB256	6V-SBM-100AH	14	7
BB257	6V-SBMD-130AH	30	15
BB258	6V-SBM-200AH	32	16
BB253	6V-SBM-205AH	44	22
BB259	6V-SBM-300AH	44	22

Charging rates materially lower than those specified on the battery name plate are undesirable because of the longer time required for charging.

2. Add distilled water as necessary to bring the electrolyte to the proper level. (art. 9622.38.)

3. Connect the positive wire from the source of charging current to the positive terminal of the storage battery and the negative wire to the negative terminal. Connect voltage leads if provision is made for them on the charging panel. Make sure that connections are tight and have ample, clean surface. Caution: Never connect or disconnect batteries with power on the battery charging leads.

4. See that the vent plug is in place and vent hole in the plug is clear.

5. If a rheostat is used to regulate the current, turn it to the off position or to a point of greatest resistance, and connect as shown in figure 9622.11. If a lamp bank is used, see article 9622.42.

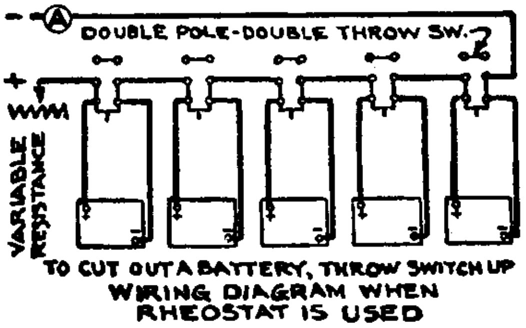


Figure 9622-11. Method of connecting a rheostat for charging.

6. Close the switch and adjust the rheostat or lamp bank until the proper charging rate is indicated on the ammeter. As the voltage of the battery rises, it will be necessary to adjust the rheostat or lamp bank to maintain this rate.

7. Take voltage, temperature, and specific gravity readings of pilot hourly while the battery is on charge. As the battery approaches the charged condition, watch the temperature readings of the electrolyte carefully. The temperature shall not be allowed to exceed 125° F.

8. When the battery begins to gas freely or when the voltage reaches 2.35 volts per cell, decrease the charging rate to the finishing rate. Never use a higher finishing rate than that given in the table in article 9622.44.1).

9. The normal charge is completed when the specific gravity corrected for temperature has reached a value within 5 points (0.005) of that obtained on the preceding equalizing charge.

9622.45 PROCEDURE IN GIVING A BATTERY AN EQUALIZING CHARGE

1. To give a battery an equalizing charge continue the normal charge at the finishing rate until hydrometer readings, corrected for temperature, taken at 30-minute intervals, show no increase in corrected specific gravity for any cell over a period of 4 hours. Temperature readings must be taken at the same time that the specific gravity readings are taken.

2. At the end of each equalizing charge temperature and voltage readings are taken at 30-minute intervals to determine when the charge should be secured. Record and compare the last set of temperature and voltage readings with the following table.

Battery Electrolyte Temperature in °F.	Cell Voltage
120	2.32
110	2.35
100	2.39
90	2.42
80	2.45
70	2.48

9622.46 FREQUENCY OF EQUALIZING CHARGES

Engine starting batteries which are charged from their own battery charging generator, and batteries which are normally on floating charge shall be given an equalizing charge at 90-day intervals; all other batteries shall be given an equalizing at 30-day intervals.

9622.47 FLOATING CHARGES

When a battery is standing idle or used on stand-by service where current demand is light, it may be put on floating charge to maintain it in a fully charged condition. If a floating charge is to be used, the rate must be governed by the battery voltage rather than by any definite current rate, adjustments being made from time to time so as to maintain the volts per cell between 2.13 and 2.17, averaging as close to 2.15 as possible. This method requires special equipment and unless the possible demand on the battery is such as to justify its use, it is better to maintain the battery by giving it monthly equalizing charges. After a period of discharge the battery should be given normal charge before being returned to the floating condition; provision for this charge is sometimes included as automatic gear on the battery charging panel.

9622.48 EMERGENCY CHARGE

1. An emergency charge may be given when it is necessary to put the maximum amount of energy into the battery in the minimum amount of time. It may be accomplished by using the constant potential charge, or the modified constant potential (multiple step) charge.

2. **Constant potential charge.** Using the constant potential method the charge is started at a rate high enough to bring the voltage up to about 2.35 volts per cell. If gassing starts, lower the voltage until the cells are gassing slightly and use this as the charging voltage. Maintain this voltage, with a steadily dropping current, until the finishing rate is reached. The finishing rate is then held constant until the charge is completed. The charge may be stopped at any time but should be completed if possible. Never use this

method of charging where cells of different sizes are to be charged in series at the same time on the same circuit. A typical charging curve is shown in figure 9622-12 a.

3. **Modified constant potential (multiple-step) charge.** Using the multiple-step method the charging rate for each step will be successively lower than the preceding step until the finishing rate is reached, at which rate the charge is completed. The charge is started at about 2.25 to 2.30 volts per cell, and the current rate obtained rate obtained at this voltage maintained until the voltage rises to 2.35 volts per cell, at which time the charging rate is dropped to some lower rate. This lower rate is continue until the voltage again rises to 2.35 volts per cell, where upon the rate is again lowered. Continue in successive steps as above until the finishing rate is reached, after which no further reduction is made. In this method of charging, all cells on charge must be of the same size. Figure 9622-12 b, illustrates the multiple-step or modified constant potential method.

4. If a voltmeter is not available, the voltage mentioned, 2.35 volts per cell, may be approximated by observing the rate of evolution of gas as there is a noticeable increase in gassing when this voltage is reached.

5. **Constant charging rates.** As a further variation of the above, if it is desired to put the maximum charge in a battery, using only a single charging rate for a definite time, the data contained in the following table may be used:

Ampere-hours out of battery	Time available for charging					
	1 hour	2 hours	$2^1/2$ hours	3 hours	4 hours	5 hours
	Amperes	Amperes	Amperes	Amperes	Amperes	Amperes
10	5.0	3.3	2.8	2.5	2.0	1.6
25	12.5	8.3	7.1	6.2	5.0	4.1
50	25.0	16.6	14.2	12.5	10.0	8.3
100	50.0	33.0	28.0	25.0	20.0	16.5
150	75.0	50.0	42.5	37.5	30.0	25.0
200	100.0	66.0	57.0	50.0	40.0	33.0
250	125.0	83.0	71.0	62.0	50.0	41.0
300	150.0	100.0	85.0	75.0	60.0	50.0

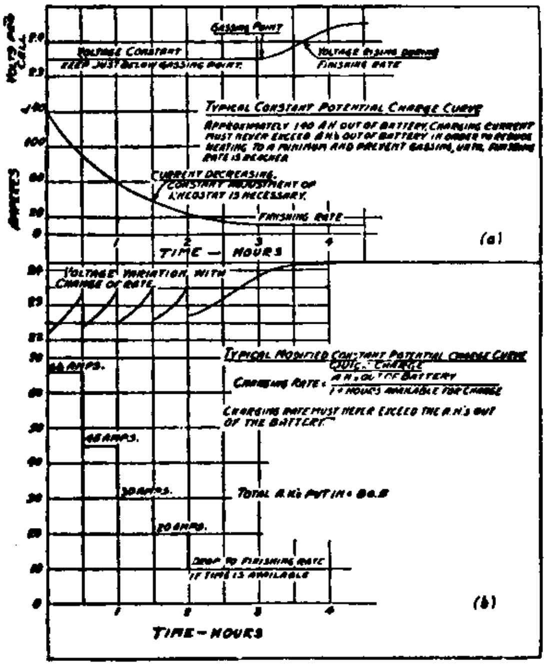


Figure 9622-12 (a) and (b). Charging curves.

9622.49 EXAMPLE OF CHARGE USING CONSTANT RATES

In using the above table first compute the ampere-hours out of the battery by the method given in article 9622.32. Enter the left-hand column of the table at the appropriate place and read across until charging rate is obtained for the time available. Charge at this rate for the time given or until the battery starts gassing, when, if more time is a vailable, reduce the current to the finishing rate. By interpolation of values given in the left-hand column, charging rates may be obtained for any value of ampere hours out of the battery. The charging rates in this table are abtained by the formula:

$$\text{Charging rate} = \frac{\text{Ampere - hours out of battery}}{1 + \text{hours available for charge}}$$

By dividing the time available for charge into several steps, considerable more charge can be put into the battery in the same length of time. Suppose 100 ampere hours are out of this battery and 2 hours are available for charging. Using 33 amperes for 2 hours, 66 ampere-hours will be put into the battery. Now, if half-hour intervals are chosen and the above formula is used, the first rate will be:

$$\frac{100}{1 + 0.5} = 66 \text{ amperes}$$

In one half hour 33 ampere-hours will be put in, and the next rate will be

$$\frac{100 - 33}{1 + 0.5} = 54 \text{ amperes}$$

In the second half hour 22 1/2 ampere-hours are put in, and the third rate will be

$$\frac{100 - 33 - 22.5}{1 + 0.5} = 30 \text{ amperes}$$

The total ampere-hours put into the battery in 2 hours = 33 + 22.5 + 15 + 10 = 80.5 ampere hours. (Figure 9622-12 b).

9622.50 FAST OR QUICK CHARGE

1. There is a method of charging which has been developed recently which is commonly called "quick charge" or "fast charge." This method of charging puts in from 60 percent to 80 percent of full charge which is considered a substantial charge in automotive service.

2. The charging rate used for quick charges in automotive service stations and garages ranges from 80 amperes to 150 amperes. These rates are maintained almost constant up to the end of charge although the increase of battery voltage causes some slight drop.

3. The voltage used varies from 2.67 volts per cell to 3.00 volts per cell.

4. The time required varies from 45 minutes to three hours depending on the condition of the battery and the method of control.

5. There are two methods of control used to stop the charge automatically.

a. **Themostatic control.** This control is operated by a thermostat placed in the center cell which actuates the control circuit when the battery reaches 125° F. At this point the battery has received all the charge that can be given safely by the "fast charge" method.

b. **Time switch control.** A time switch set for a predetermined length of charging time automatically stops the charge when this time period has elapsed. The length of time for the charge is determined by a test made on the battery before charge begins.

6. The advantages of this method of charge are:

a. A substantial charge is given the battery in the shortest possible time. 60 percent to 80 percent of full charge will operate all the equipment on an automobile. If the vehicle's charging equipment is operating properly the charge will be finished off by it.

b. Much time is saved by finishing the charge in three-fourths of an hour to three hours instead of 12 to 24 hours.

c. Labor is saved by making it unnecessary to disconnect the battery and replace it while charge is going on.

7. The disadvantages of this method of charging are:

a. The high rates of charge cause rapid gassing which may result in flooding of electrolyte out of the battery.

b. High temperatures result, which, if often repeated, will damage the battery.

c. Rapid rates of gassing will cause the positive active material to be broken from the positive plates.

d. Repeated use of these high rates of charge will peroxidize the positive grids.

e. Special equipment is required to give a battery a "fast charge."

8. It is considered that the disadvantages overbalance the advantages for shipboard use. Therefore, this method of charge is not recommended.

9622.51 WHEN TO REDUCE CHARGING RATE TO FINISHING RATE

1. When a battery nears full charge, it begins to gas freely and the voltage rises to about 2.35 volts per cell. When gassing begins near the end of charge, the charging current must be decreased to the finishing rate, to avoid heavy gassing.

2. **Why gassing is objectionable.** Excessive gassing is an indication of too rapid charging and a waste of energy. It is objectionable because the gas bubbles tend to loosen the active material from the plates and eventuall cause disintearation of the positive grids. The active material so loosened is precipitated to the bottom of the cell, resulting in loss of battery capacity. Should this accumulation reach the bottom of the plates, an internal short circuit will result. Excessive gassing also increases the danger of a battery explosion.

9622.52 LIMITING TEMPERATURE ON CHARGE

During charge a battery will heat up, the temperature rising from 10° to 20° F. The temperature of the electrolyte shall never exceed 125° F. When this temperature is reached, the rate of charge shall be reduced, or the charge discontinued until the battery has cooled off.

9622.53 REASONS FOR VENTILATION

1. Ventilation of the battery compartment is necessary:

a. To prevent the formation of an explosive mixture during a charge.

b. To serve as an incidental aid in keeping battery temperatures down.

c. To remove hydrogen from battery compartments which have been sealed.

2. Air containing from 4 to 8 percent hydrogen forms a mixture which will burn if ignited. Mixtures containing more than 8 percent hydrogen will explode. Ample ventilation is necessary to keep the hydrogen concentration below the safe limit-3 percent. Batteries should never be located in bilges as it is impossible to provide adequate ventilation in this space. With large numbers of batteries concentrated in a single station the problem of ventilation becomes serious, and great care must be exercised to insure that ventilating apparatus is working at all times. Fresh air from the exterior of the vessel should be provided if possible, and exhaust from the battery station should lead overboard. Remember that battery explosions are dangerous and will result in injury to personnel. See Chapter 38 for ventilation.

3. Battery charging stations should be insulated from outside heat sources and every effort be made to keep the temperature down to 95° F. or lower. Since the limiting temperature of a battery is 125° F., it is desirable to keep the battery charging station temperature below 100° F. in order to facilitate charging.

9622.54 KEEP FLAMES AND SPARKS AWAY FROM BATTERY

Since a certain amount of gas is given off from a battery at all times, flames or sparks of any kind must never be allowed in the vicinity of any storage battery. Extra care is necessary after opening a battery compartment which has been sealed. No light switches shall be turned on, no electrical connections of any kind shall be made or broken, and no work shall be performed in the compartment until it has been thoroughly ventilated.

9622.55 KEEP VENT PLUGS IN PLACE

In order to prevent electrolyte from spraying out and the entry of foreign matter, vent plugs must be kept in place and tightened at all times except when taking temperature and specific gravity readings or when adding water. The vent hole in the plug should always be kept free of obstructions.

9622.56 CAPACITY OF A BATTERY

Batteries are rated by their ampere-hour capacity at some definite rate of sidcharge. Navy batteries are rated at the 10-hour rate. The capacity of a battery varies with the rate of discharge; the lower the rate of discharge, in amperes, the greater the capacity. The following table gives the approximate relative ampere-hour capacities obtainable from a typical battery at different rates.

Rate of discharge	Ampere-hour capacity (percent)
1-hour	55
2-hour	65
3-hour	75
6-hour	90
10-hour	100

9622.57 BATTERY RECORDS

Where applicable, Ship Maintenance Cards will be used in lieu of form NavShips 151, "Storage Battery Tray Record". This form shall be inspected and approved monthly by the electrical officer (or in the case of radio batteries by the radio officer) and note of such inspection and approval shall be made on the form at that time. The record shall accompany the battery tray whenever transferred. It may be destroyed when the service of the battery is terminated. NavShips 151 shall be kept when Ship Maintenance Cards are not used.

Part 5. Care and Upkeep

9622.61 NECESSITY FOR PROPER CARE

Lead acid storage batteries will deteriorate rapidly unless given proper care. When cared for properly, they will give a useful life of 4 or more years, depending upon the type and use.

9622.62 BATTERY CARE DEPENDENT ON TYPE OF SERVICE

1. The service for which a battery is used primarily determines the nature of care and maintenance which will insure maximum reliability and life.

2. **Engine starting batteries.** Because of the heavy drain on batteries used for starting propulsion engines, motor boat engines, or ship's service engine-generator sets, they are particularly liable to damage by failure of the generator to charge the battery adequately due to:

a. Frequent starts or short periods of engine operation.
b. Low charging rate on the generator.
c. Extreme cold weather starting conditions.
d. A particularly "tight" (now or recently overhauled) engine.

These batteries, therefore, require frequent checking by competent personnel to insure that they are being properly maintained. Due to the extreme importance of getting a vessel under way in any circumstances, proper maintenance of propulsion engine starting batteries cannot be stressed too highly. During inspections particular attention should be paid to the electrolyte level and specific gravity. If the specific gravity has fallen 30 points below the prescribed operating gravity the battery should be given an equalizing charge. Care should also be taken to insure that the battery is not being overcharged by the generator. The desired generator charging rate and voltage regulator or voltage relay cutoff settings (if the generator is equipped with a voltage regulator or if a voltage relay is installed) are those which will maintain the specific gravity of the electrolyte above the figure which is obtained by subtracting 20 points from the prescribed operating specific gravity. Keep engine starting batteries clean and dry and free of salt water. At the beginning of a period of inactivity for the vessel of a week or more, give the battery a normal charge. During a period of inactivity arrangements should be made to give the battery an equalizing charge only if thirty days have elapsed since the last equalizer, or the specific gravity reaches a value 30 points below the required gravity, whichever comes first.

3. **Standby Batteries.** Batteries on standby service, such as auxiliary lighting and power batteries, are rarely discharged by actual use. A normal healthy battery on open circuit will discharge 50 percent or more in 3 to 4 months' time. This is a normal condition and is caused by minute cells set up by the different materials in the individual plates, grids, and active material, and is usually called local action or self-discharge. The lead sulphate so formed differs from that formed in a regular discharge and is much harder to reduce by charging. For this reason such batteries should be given an equalizing charge when the specific gravity drops to 1.180, and at 30-day intervals regardless of specific gravity, if on open run circuit and not delivering power. If such batteries show signs of decreasing specific gravity on the monthly equalizing charges, they should be cycled to restore them to a healthy condition. Discharge may be provided by using these batteries for the purpose for which they were provided as standby units. Batteries on standby service must be inspected weekly for cleanliness, need of water, tightness of connections, and the specific gravity and temperature of all cells taken and recorded.

4. **Telephone, Fire Control, and I. C. Batteries.** Standby batteries for services such as battle telephone, fire control, and interior communication are usually floated on a supply line from low-voltage motor generators through reverse current circuit breakers. Batteries for automatic telephones are usually intermittenely charged automatically from motor generators supplying the system. In case of failure of the motor generators, the storage battery automatically takes over the load, and the generator is cut out of the system. Care should be taken in adjucting the voltage of such generators to avoid excessive potentials with consequent overcharging.

5. **Gunfiring Batteries.** Batteries used for gunfiring and sight lighting purposes are idle a large part of the time. Such batteries should be given equalizing charge at least once a month or when the specific gravity drops to 1.180 in order to assure performance. Batteries at 1.180 specific gravity will freeze at 9° F. Batteries which are exposed to low temperatures should be kept well charged to avoid freezing (see art. 9622.69) and should be cycled and given periodic inspection as described in paragraph (3) above.

6. **Counter E. M. F. cells.** Counter E. M. F. cells are used to produce an opposing voltage in order to reduce the voltage of one circuit to the desired lower voltage on a dependent circuit, for example, in automatic telephone circuits. They have the outward appearance of the usual storage battery tray and are distinguished by the letters "CEMF" on the name plates. They are made of electrodes immersed in an electrolyte but have no storage capacity. Counter E. M. F. cells perform substantially the same functions as a rheostat but differ from the latter by interposing a fairly constant voltage. In a rheostat, the IR drop is in proportion to the current and the electrical energy is converted into heat. In operation, the counter E. M. F. cells, decompose the water in the electrolyte practically in proportion to the ampere-hours which pass through them with the evolution of gas, and, therefore, the cells will need to be filled with water from time to time. Theoretically, if all of the electrical energy were absorbed by the evolution of gas, which would be the case if platinum or gold electrodes were used, there would be no attack on the electrodes themselves. Practically, antimony-lead alloy, which is fairly resistant to corrosion, is used, and, therefore, the positive electrode is slowly oxidized and ultimately requires replacement; there is no deterioration of the negative electrodes in any case.

9622.64 TEST DISCHARGE TO DETERMINE BATTERY CAPACITY

1. The capacity of a battery is determined by carrying out a test discharge. Such a discharge may be performed on board ship if the necessary equipment is available; if not available, on board a tender or repair ship, or at a Naval shipyard or other shore establishment.

2. Give the battery a test discharge to determine battery capacity as follows:

a. After four years service.

b. If functional testing is not performed, whenever the voltage after charge is satisfactory (equal to or greater than the figure given in article 9622.45 (2) but the specific gravity of one or more cells cannot be brought up to within 0.010 of the full charge or

c. Whenever any cell has a charge voltage which is less than that shown in 9622.45 (2) for the corresponding electrolyte temperature.

d. The above requirements for the capacity test discharge are only applicable to the portable storage battery classes listed in article 9622.2.

3. To insure that reliable data may be obtained, a test discharge must be preceded by an equalizing charge (arts. 9622.45 and 9622.132.2). Immediately following the equalizing charge, the battery should be discharged at the 10-hour rate until either the total battery voltage drops to value which is equal to 1.75 times the number of cells in series, or the voltage of any individual cell drops to 1.65 volts, whichever occurs first. Navy standard batteries are rated upon the 10-hour capacity; thus, the correct discharge rate for a 200 ampere-hour battery would be 200/10 = 20 amperes and must be kept constant throughout the discharge. For a battery of 100 percent capacity, the discharge will continue for a period of 10 hours before reaching either of the low-voltage limits mentioned above provided the temperature of the electrolyte at the beginning of the discharge is exactly 80° F. If the temperature of the electrolyte at the beginning of the discharge is not exactly 80° F., the time duration of the discharge for 100 percent capacity must be corrected for the actual temperature of the electrolyte existing at the start of the test. The correction in time of discharge may be determined from the following table:

Temperature F°. of electrolyte at beginning of discharge	**Minutes -- Subtract minutes indicated from 10-hour period**
50	133
55	108
60	83
65	60
70	36
75	15
80	0
	Add minutes indicated to 10-hour period
85	7
90	13
95	18
100	25
105	30
110	35

It should be noted that the corrections given in the above table apply to the 10-hour rate only.

4. The test discharge should be made through a rheostat or other loading device which is adjustable through a range sufficient to permit the discharge rate to be maintained constant in value throughout the discharge.

5. The percent of ampere-hour capacity is computed from the following:

$$C = \frac{Ha}{Ht} \quad X100;$$

Ha = total actual hours of discharge
Ht = total hours for 100 percent capacity. (See art. 9622.64.2).
C = percent of ampere hour capacity.

6. Data on the percent capacity obtained on each test discharge taken on a storage battery shall be recorded on either the maintenance card or NAVSHIP 151.

7. If the percent ampere-hour capacity is 80 percent or more, the battery is to be kept in service; if it is less than 80 percent, it is to be treated in accordance with the provisions of article 9622.132.5).

8. Where a battery test discharge panel, in accordance with NAVSHIPS drawing 9000-S6201-74397 is available, the test discharge may be made at the 2-hour rate. The discharge current at the 2-hour rate is found from the relation:

$$I = \frac{0.65\ AH}{2}$$

a. Where I is the discharge current in amperes, AH is the 10-hour rate ampere-hour capacity.

b. The battery should be discharged at the 2-hour rate, until either the total battery voltage drops to a value which is equal to 1.60 times the number of cells in series, or the voltage of any individual cell drops to 150 volts, whichever occurs first. The correction for temperature in the time of discharge at the 2-hour rate may be determined from the following table:

Temperature F°. of electrolyte at beginning of discharge	Minutes subtract minutes indicated from 2-hour period
50	33
55	27
60	21
65	15
70	9
75	5
80	0
85	2
90	4
95	5
100	7
105	8
110	9

9. If the percent ampere-hour capacity at the 2-hour rate is 80 percent or more, the battery is to be kept in service, if it is less than 80 percent, it is to be treated in accordance with the provisions of article 9620.332.5.

9622.65 ROUTINE INSPECTION FOR HEIGHT OF ELECTROLYTE

Pilot cells (see art. 9622.26) shall be inspected for height of electrolyte once each week or more often if experience shows this to be necessary. The electrolyte level shall never be allowed to fall below the tops of the separators.

9622.66 ADDING WATER AND ACID

1. Pure distilled water may be added at any time to replace that which has evaporated. It is perferable, however, to add water just before the battery is placed on charge, as the water remains on top of the electrolyte until mixed with it by charging. If the water is allowed to remain on top of the electrolyte in cold weather, it may freeze, cracking the monobloc cases or jars.

2. After adding water, the vent plugs should be replaced and tightened. If they are not tightened, the electrolyte will spray out when charging, and the resultant loss of electrolyte will cause a decrease in battery capacity. Remove all water or electrolyte spilled during the watering, and make sure that the tops and sides of the cells are clean and dry.

3. **Battery water.** Distilled water which is to be used for watering batteries and mixing electrolyte shall contain not more than the following maximum allowable impurities:

Impurities	Percent
Suspended matter (lead compound only)	Trace
Total solids	.01
Calcium and magnesium oxides	.004
Iron	.00005
Chlorine	.0005
Organic and volatile matter	.005
Nitrites as NO_2	.0005
Nitrates as NO_3	.001

4. Nothing but water of the purity specified above shall ever be added to a battery except when it is necessary:

a. To replace electrolyte spilled from a battery; or

b. To adjust specific gravity (art. 9622.67). In these cases, pure electrolyte is added. Nothing but pure water or pure electrolyte shall ever be added to a battery at any time.

9622.67 LIMITS ON SPECIFIC GRAVITY

1. The capacity of Navy standard portable batteries, except class 2V-SBP-20AH, is based upon a fully charged specific gravity between the limits of 1.220 specific gravity at 80° F. Class 2V-SBP-20AH batteries are always operated with electrolyte gravity between the limits of 1.270 and 1.285.

2. The specific gravity of a battery, or cell which has fallen below the above limits shall not be increased by the addition of acid except by authorized repair personnel at naval shipyards, or other shore establishments, or on board repair ships and tenders, and then only when it has been definitely ascertained by test that the low-gravity condition is not due to sulphation. The addition of acid to increase the specific gravity of a sulphated cell will aggravate the existing condition. With proper care there should be no less of acid from the electrolyte, and, therefore, little need should arise for adding acid to restore the specific gravity of a healthy cell.

3. **Reducing specific gravity.** Excepting type 2V-SBP-20AH batteries, and except as indicated in article 9622.67 4 and 5, the specific gravity of a cell shall not be allowed to remain above the upper limit of 1.220. The specific gravity of cells which exceed this limit shall be cut by the removal of an appropriate amount of electrolyte and the addition of distilled water. (See art. 9622.112.3).

4. **Raising specific gravity.** All Navy portable storage batteries, except class 2V-SBP-20AH, are assembled with 1.210 to 1.220 specific gravity electrolyte when fully charged. If the operating personnel fine that the weather conditions under which any 1.210 to 1.220 specific gravity batteries are required to operate result in temperatures consistently below 40° F., authority is granted to raise the specific gravity by the addition of diluted acid to within the limits of 1.270 to 1.285, average 1.280 specific gravity upon request to naval shipyards, or other shore establishments, or on board repair ships or tenders by authorized personnel. (See art. 9622.112.2.) Whenever this is done, notation shall be made on the storage battery tray record. When weather conditions moderate, resulting in operating temperatures consistently higher than 40° F., the specific gravity of these batteries shall be reduced to within the limits of 1.210 to 1.220 specific gravity by removing electrolyte and adding pure distilled water and further notation made on the storage battery tray record.

5. In order to provide the necessary starting capacity in some installations of class 6V-SBMD-130AH and 6V SBMD-205AH, the batteries have been installed with the specific gravity of 1.270 to 1.285. For proper operation of equipment, the specific gravity should be left at this point.

In the event that certain special batteries have been assembled with a specific gravity other than those mentioned herein, this specific gravity shall be maintained at all times.

6. Sulphuric acid of a specific gravity greater than 1.350 shall not be added to a battery. Mixing acid, if it is of higher specific gravity than this shall be diluted to 1.350 or below before being poured into a battery.

9622.69 PRECAUTIONS IN STORING ACID

1. Carboys containing sulphuric acid shall be stored in a place where freezing cannot occur. The freezing temperature of sulphuric acid electrolyte is as follows:

Specific gravity:	**Temperature (°F.)**
1.150	+ 5.0
1.210	-23.0
1.250	-61.0
1.280	-91.0
1.300	-95.0
1.350	-56.0
1.400	-33.0
1.500	-20.0
1.700	+6.0
1.726	+27.3
1.768	+46.1
1.790	+46.4
1.796	+43.6
1.800	+42.0
1.807	+37.9
1.812	+33.1
1.818	+24.6
1.824	+13.4
1.830	-1.0
1.835	-29.0

Note.—Between 1.614 and 1.667 specific gravity, the freezing point is indeterminate, below -40° F.

2. It will be noted from the above table that a reduction of specific gravity of concentrated acid from 1.835 to 1.800 changes the freezing temperature from -29° to +42° F. Since sulfuric acid is highly hygroscopic, extreme care must be taken to insure that carboys are absolutely airtight. The entry of even a small quantity of water into an open carboy may reduce the specific gravity sufficiently to cause the jar to break in cold weather, due to freezing, with the consequent grave danger of bad acid burns to personnel.

3. At any temperature, the addition of even a small quantity of water to a carboy of strong sulfuric acid may cause an explosion owing to the sudden evolution of heat.

9622.70 MIXING OF ELECTROLYTE

1. To prepare the electrolyte, lead or rubber vessels and stirring rods are necessary. Only pure distilled water and sulphuric acid purchased in accordance with Federal Specification O-S-811 shall be used. Every effort must be made to keep impurities from the electrolyte while mixing, since they short battery life. The following table gives the amounts of water and acid to be used to make electrolyte of a desired specific gravity.

2. **Precautions while mixing electrolyte.** In mixing electrolyte the acid must be poured into the water and not the water into the acid. It must be added slowly to the water to prevent excessive heating, and cautiously to prevent splashing, as the acid will cause painful burns. The solution should be stirred continually while the acid is being poured into the water to prevent the heavier acid from flowing to the bottom of the vessel without mixing. When the concentrated acid is diluted, the solution becomes very hot.

Data for preparing electrolyte from acid

Desired electrolyte (specific gravity)	Weight of water per unit weight of acid			Volume of water per unit volume of acid			Pounds of acid to make 100 pounds of electrolyte			Gallons of acid to make 100 gallons of electrolyte		
	1.350	1.400	1.835	1.350	1.400	1.835	1.350	1.400	1.835	1.350	1.400	1.835
1.10	1.98	2.33	5.21	2.67	3.26	9.55	33.6	30.0	16.1	27.5	23.7	9.7
1.11	1.71	2.03	4.66	2.31	2.84	8.45	36.9	33.0	17.7	30.5	26.3	10.8
1.12	1.51	1.81	4.24	2.04	2.53	7.79	39.8	35.6	19.1	33.2	28.6	11.7
1.13	1.34	1.62	3.89	1.81	2.27	7.15	42.7	38.2	20.4	35.9	30.9	12.6
1.14	1.19	1.45	3.58	1.61	2.03	6.57	45.7	40.8	21.8	38.7	33.4	13.6
1.15	1.05	1.30	3.28	1.42	1.82	6.02	48.8	43.5	23.3	41.7	35.9	14.7
1.16	.95	1.18	3.07	1.28	1.65	5.63	51.3	45.8	24.6	44.3	38.2	15.6
1.17	.85	1.07	2.86	1.15	1.50	5.25	54.0	48.3	25.9	47.1	40.5	16.6
1.18	.75	.96	2.65	1.01	1.35	4.87	57.2	51.0	27.4	50.1	43.2	17.7
1.19	.67	.87	2.49	.90	1.22	4.57	59.8	53.5	28.6	53.1	45.8	18.7
1.20	.59	.78	2.31	.80	1.09	4.24	62.8	56.2	30.2	56.2	48.5	19.9
1.21	.52	.70	2.18	.70	.96	4.00	65.7	58.8	31.4	59.4	51.2	20.8
1.22	.46	.64	2.05	.62	.90	3.76	68.5	61.0	32.8	62.3	53.5	21.9
1.23	.41	58	1.94	.55	.81	3.56	70.9	63.3	34.0	65.0	56.0	22.9
1.24	.36	.52	1.83	.49	.73	3.36	73.5	65.8	35.3	68.0	58.6	24.0
1.25	.31	.46	1.73	.42	.64	3.17	76.3	68.5	36.6	71.1	61.5	25.1
1.26	.26	.42	1.64	.35	.59	3.01	79.4	70.5	37.9	74.5	63.7	26.2
1.27	.22	.37	1.55	.30	.52	2.84	82.0	73.0	39.2	77.5	66.6	27.3
1.28	.18	.32	1.47	.24	.45	2.70	84.7	75.7	40.5	80.8	69.6	28.4
1.29	.15	.29	1.40	.20	.41	2.57	87.0	77.5	41.7	83.5	71.8	29.5
1.30	.12	.25	1.33	.16	.35	2.44	90.2	80.0	42.9	86.5	74.6	30.6
1.31	.09	.22	1.27	.12	.31	2.33	91.7	82.0	44.0	89.5	77.2	31.6
1.32	.06	.18	1.20	.08	.25	2.20	94.3	84.7	45.5	92.7	80.3	32.9
1.33	.03	.15	1.15	.04	.21	2.11	97.0	87.0	46.5	96.1	83.0	33.9
1.34	0	.12	1.09	0	.17	2.00	100.0	89.3	47.8	100.0	86.0	35.1
1.35	------	.09	1.04	-------	.13	1.96	-------	91.7	49.0	-------	89.0	36.2

Note. Specific gravity of acid is at 60° F./60° F. which conforms to specification O-A111. Specific gravity of electrolyte is at 80° F./60°F.

3. **Lead Acid Battery Dopes.** No satisfactory substitute electrolyte has been found for the simple mixture of sulfuric acid in water. The use of a substitute or additive may injure the battery and void the manufacturer's guarantee.

4. **Effect of acid gravity.** The Navy type batteries generally use 1.215 specific gravity sulfuric acid. The low initial acid gravity and heavier battery construction favors longer life. Stronger acid (higher initial specific gravity) increases the battery capacity. For example, the BB-257 gives 130 ampere–hours at the 10 hour rate when 1.215 specific gravity acid is used. The rated capacity is increased to 175 ampere hours by using 1.280 specific gravity acid, but the cycle life is reduced.

9622.71 CARE IN HANDLING ACID

1. Men handling or mixing electrolyte shall wear rubber aprons, rubber boots, and rubber gloves, so that the acid may not come into contact with clothing or skin. In particular, the eyes must be guarded by goggles.

2. **Treatment of acid burns.** Should a man get concentrated acid or electrolyte on his skin, wash the affected place freely with a **large quantity** of fresh water, apply vaseline, petroleum jelly, boric acid, zinc ointment, or, if none of these is available, clean lubricating oil, and send him to sick bay. A small amount of water may not only be ineffective in preventing a serious burn, but may even do more harm than good. If electrolyte or concentrated acid gets into the eye, first wash **plenty** of frest water. Repeatedly squeeze out a saturated gauze sponge or wad of cotton held above the eye, the stream being directed into the pocket formed by pulling the lower lid outward. Do not use a syringe nozzle or any other pressure method for this purpose because of the danger of mechanical injury to the eye. Quick action is necessary. Then wash the eye with a solution made by mixing two tablespoonfuls of baking soda with a pint of water, apply clean mineral oil or liquid petrolatum, and send the man to sick bay. In case an ample supply of fresh water is not available, sulphuric acid may be neutralized by applying quickly to the affected place a solution of sodium bicarbonate (baking soda).

9622.72 TESTING ACID OR ELECTROLYTE

If it is desired to test electrolyte at any time, a sample should be sent to a Naval shipyard chemist. The limit of allowable impurities is in accordance with the following table:

Impurities	Determined as	Maximum Percent
Iron	Fe	0.012
Copper	Cu	.005
Chlorine	Cl	.012
Arsenic	As	.0001
Antimony	Sb	.001
Nitrates	NO_3	.002
Manganese	Mn	.00006
Platunum	Pt	None
Suspended matter		(1)

[1] Lead compounds only.

9622.73 HYDROMETER READINGS

1. In taking hydrometer readings care should be exercised not to spill any electrolyte. Loss of even a few drops each time a reading is taken will in time result in a full charge gravity of pilot cells lower than that of other cells.

2. In reading the hydrometer, hold it so that the eye is at the same level as the surface of the liquid, and not the scale reading at the bottom of the curved surface of the liquid, or meniscus. Be sure the float is floating freely in the hydrometer syringe barrel.

3. Hydrometer readings taken when the battery is gassing may read too low by as much as 5 to 10 points gravity, owing to the presence of minute bubbles of gas. To obtain accurate readings under this condition, the electrolyte in the hydrometer barrel must be given time to clear before the reading is taken.

9622.74 CORRECTIONS APPLIED TO HYDROMETER

1. In order to establish a uniform basis for comparison it is important that all specific gravity readings taken when charging, discharging, or when mixing acid be corrected to 80° F. To correct to this temperature add 0.001 to the hydrometer reading for each 3° The temperature is above 80° F. and subtract 0.001 for each 3° the temperature is below 80° F. For example: A reading of 1.211 at 92° F. equals 1.215 at 80° F., and a reading of 1.220 at 65° F. equals 1.215 at 80° F. A correction scale is provided which may be read directly on all thermometers furnished with type B testing outfits. (Military Specification MIL-T-16384).

2. **Keep hydrometers clean.** Hydrometers used on storage batteries must be used for no other purpose. They should be flushed with fresh water daily to prevent the accumulation of sticky substances inside the glass barrel. These substances gradually gather on the hydrometer float, causing readings to be inaccurate. If such substances have collected on the barrel or hydrometer, take the hydrometer apart, clean with an ammonia solution, rise with clean water, and dry with a clean cloth. Allow the parts to air before they are reassembled.

3. When assembling or disassembling a hydrometer, a heavy piece of cloth should be wrapped around the glass barrel to prevent personal injury in case of glass breakage. During reassembly the rubber bulb should be slightly moistened with water where the rubber contacts the glass barrel. This will reduce the amount of pressure or torque required to replace the bulb.

9622.75 TEMPERATURE READINGS

To obtain accurate temperature readings, the mercury bulb of the thermometer must be completely immersed in the electrolyte for at least 30 seconds. The thermometer should be read while still immersed in the electrolyte.

9622.76 BATTERY CLEANLINESS AND CARE

1. All batteries and battery lockers must be kept clean and free of all foreign matter. Clothing, cloth, or wiping rags should not be allowed to remain in battery rooms or lockers. When vent plugs are removed from cells, care must be taken to prevent anything falling therein. Avoid spilling acid or water. Collections of acid or dirt around a battery will lead to troublesome grounds and will cause corrosion. After each watering, the tops of cells and sides of jars should be wiped clean.

2. If acid has accumulated, it may be removed by wiping clean with a cloth moistened in a dilute ammonia solution or bicarbonate of soda solution. In using ammonia or bicarbonate of soda care must be observed that it does not enter the cell.

3. Keep tne battery connections and bolts covered with a light film of petrolatum (Navy Department Specification 14 P1) or cup grease (Military Specification MIL-G-15793), as this will prevent acid from reaching them. If these parts are attacked by acid, a sulphate is formed which will make it difficult to disconnect leads from terminals, and the resistance of the terminal connections is increased which lowers the voltage on discharges.

4. At the end of each watering all cell connections should be checked for tightness. If sulphate has formed at the terminals, it must be removed and petrolatum applied.

9622.79 BATTERY GROUNDS

Battery grounds are undesirable for the following reasons:

1. A ground in the vicinity of the battery may furnish the spark necessary to ignite an explosive gas mixture, if present.

2. A ground on the battery may cause disarrangement of the complete circuit of which the battery is a part.

3. Battery grounds cause dissipation of battery energy.

4. Grounds may be formed by dirty or acid wet cell tops and sides, the path of the ground in this case being from the terminals, along the jar sides, to the battery racks, and finally to the ship's hull. A loss of charge by direct leakage from terminal to terminal may occur to the presence of dirt and moisture without an actual path to ground exising.

9622.81 LOW CELLS

1. The most common trouble encountered in the operation of storage batteries is that of low cells. This condition may be brought about by various causes, such as poor connections, sulphation, loss of active material, local action, short circuits, loss of electrolyte, hardened negatives, disintegration of positive grids, broken positive pencils (ironclad), and impure electrolyte. It may be detected by progressive loss of capacity, low voltage on discharge, low specific gravity, comparatively high or low voltage on charge, and comparatively high temperature. The gravity of low cells will usually be below that of the other cells on charge and discharge.

2. Any cell with which trouble is being experienced should be examined immediately for low electrolyte and poor connections, and portable voltmeter readings at the cell terminals should be taken while the battery is being charged or discharged. If the portable meter voltage reading is much higher or lower than that of normal cells, the trouble probably lies within the cell itself, and must be investigated further.

9622.83 SULPHATION

1. Sulphation is one of the causes for failure of cells to maintain their normal health. But before finally attributing a faulty condition to sulphation it should be definitely ascertained that the condition has not been occassioned by other causes. Many cases of low cells are erroneously attributed to sulphation and the actual defective condition aggravated by consequent sulphation treatment.

2. **Indications of sulphation.** A sulphated cell may be indicated by one or more of the following conditions: falling off of specific gravity; low voltage on discharge; and loss of capacity. Sulphation is usually evidenced upon inspection of the element, but only after a normal charge since a discharge plate is always somewhat sulphated. A charged negative plate in normal condition is spongy and shows metallic luster and a dragging of the material when wiped with a flat blade. A sulphated negative plate will not show metallic luster and the material lacks cohesion, being usually hard and gritty. A sulphated positive plate is a lighter brown color than the normal plate.

3. Most cases of sulphation are caused by:

a. Undercharging, partial charging, or neglect of equalizing charge.

b. Standing in a partially or completely discharged condition.

c. Low electrolyte.

d. Adding acid.

e. High specific gravity.

f. High temperature.

4. a. The practice of giving undercharges or partial charges, or the neglect of equalizing charges will bring about a sulphated condition. It is difficult in normal battery operation to determine just when sulphation begins and only by giving periodic equalizing charges and comparing individual cell specific gravity and voltage readings can it be detected in its early stages and corrected or prevented. Equalizing charges must be given as frequently as required by article 9622.46

b. Permitting a battery to stand in a partially discharge condition allows the sulphate deposited on the plates to harden and the pores to close, which is the condition of sulphation. Batteries should be charged as soon as practicable, after discharge. Under no circumstances shall any battery be allowed to stand in a completely discharged condition for more than 24 hours.

c. If the level of the electrolyte is permitted to fall below the tops of the plates, the exposed surfaces will harden and become sulphated.

d. If acid is added to a cell in which sulphation exists, the condition will be aggraviated.

e. In general, the higher the fully charged specific gravity of a cell the more likely is sulphation to occur and the more difficult to reduce. If, in any battery there exist cells of which the specific gravity is more than 0.015 above the average, the possibility of sulphation of these cells will be increased.

f. High temperatures accelerate sulphation, particularly of an idle, partially discharged battery.

5. Sulphation of a battery, except in extreme cases, may be reduced by a long charge finished at a low rate. This procedure is necessary in order to break down the sulphate which has not been reduced by normal charges. The charge should be started at the highest available rate which can be utilized without excessive gassing, and continued at progressively reduced rates to keep within allowable temperature limits until the charging current has been reduced to a finishing rate in amperes equal to approximately:

$$FR = \frac{1.1 \times AH_{10}}{20} = .055 \times AH_{10}$$

Where:

FR = finishing rate, amperes

AH_{10} = ampere hour capacity at 10 hour rate

The charge should then be continued at this rate until the specific gravity and voltage are constant for a period of 5 hours. The measure of the results of this treatment is a comparison of the specific gravity and voltage readings obtained at the end of the 5-hour charge period with similar readings shown by healthy cells of the battery, considered in conjunction with the capacity of the battery as indicated by a test discharge. If that comparison is satisfactory, no further treatment is necessary; if unsatisfactory, the treatment specified above should be repeated.

9622.85 LOSS OF ACTIVE MATERIAL

Loss of active material may be determined by a visual inspection of the plates and by measuring the amount of sediment in the bottom of the jar. In all batteries there is a normal loss of active material owing to erosion caused by gassing at the end of charge. Excessive loss of active material results in a reduction of capacity. When excessive shedding is not the result of improper design, it may be caused by undue gassing, by overcharging, or by expansion brought about by high temperatures. This is also a sign of wear and is often evident in batteries that have given long service.

9622.86 LOCAL ACTION

Local action is indicated by excessive drop in the specific gravity of the electrolyte while the cell is on open circuit and by excessive gassing on an open circuit and on discharge. In general, the higher the specific gravity the greater the tendency for local action and the more rapid the fall in gravity while the battery is standing idle. Local action is caused by nonhomogeneity of, and by impurities in, the material in the plates or by impurities in the electrolyte, the most common of which is iron. If impurities are suspected, the electrolyte should be dumped, the plates rinsed with distilled water, and the cells refilled with new electrolyte of the same specific gravity as that discarded.

9622.87 SHORT CIRCUITS

1. Short circuits are indicated by abnormal temperature, low specific gravity, low voltage and by reduced gassing on charge. Short circuits may be caused by:

   a. Faulty separators.

   b. Lead particles or other metal forming a circuit between the positive and negative plates.

   c. Buckling of plates resulting in direct contact of positive and negative.

   d. Excessive accumulation of sediment in bottom of jar.

   e. Mossing, usually between the tops of the negative plates and the positive straps.

   f. A crack in a partition between cells in a monobloc hard-rubber case.

2. A cell containing a short circuit will gradually discharge itself, and will become unduly heated on charge. The element should be removed and carefully examined for the cause. If the short circuit is caused by mossing or sediment, it should be removed and the element replaced in the container. If the separators are damaged or the plates show a condition of bad wear, the element should be replaced. If cracks in the case are found after internal examination, the case should be renewed.

9622.88 LOSS OF ELECTROLYTE

Loss of electrolyte is indicated by excessive drop in electrolyte level in comparison with normal cells. This indicates a crack in the jar.

9622.89 HARDENED NEGATIVES

Hardened negative plates is a condition in which the active material is hard and nonporous. It is caused by insufficient charging. It may be detected by scratching the active material with the thumbnail. A healthy plate is easily scratched to a bright metallic luster.

9622.90 REVERSAL OF CELL VOLTAGE

1. If a low cell is discharged much below the low-voltage limit in series with other cells, it will reverse its polarity. If a cell reverses polarity before adjacent cells are near their voltage limit, it should be assumed that this condition is caused by faults within the cell itself.

2. A reversed cell may be detected by the voltage reading of the cell. The presence of a reversed cell in a battery will be indicated by a rapid fall in the battery voltage; this may be as much as 3 to 4 volts, because the cell voltage may charge from 1.7 volts in the right direction to as much as 2 volts in the reverse direction in a short time. Except in an emergency, as soon as a reversed cell is discovered the charge must be discontinued until the cell or tray is cut out.

9622.92 BATTERIES EXPOSED TO COLD TO BE KEPT CHARGED

Batteries in exposed locations which are subject to low temperatures shall be kept charged during cold weather and should, in extremely cold weather, be removed to a warm room, if possible. (See article 9620.269 for freezing temperature of electrolyte of various densities.)

9622.93 ROUTINE CARE FOR BATTERIES

The conditions under which batteries are used vary from ship to ship. The frequency of inspection necessary to make sure that batteries are in good operating condition will also vary to some extent. The following are considered to be the minimum requirements consistent with good engineering practice for average operating conditons. In all cases where experience indicates that inspections as scheduled below are not sufficient to ensure that batteries will be ready and able to perform their functions whenever needed, the frequency of inspection should be increased as necessary. In cold weather operations, for example, daily inspection of boat batteries may be necessary.

1. **Daily.** See that all parts of the ventilation system in battery rooms and battery lockers are in proper condition. Clean battery hydrometers (article 9622.74.2).

2. **Weekly.** Observe the height of electrolyte in pilot cells (article 9622.26) and take and record pilot cell specific gravity and temperature readings for all batteries. Water batteries if the height of electrolyte in pilot cells is at the low mark or will drop below the low mark before the next weekly inspection. (See article 9622.65.) Check the charging rate of engine battery charging generators (article 9622.62.2.) and voltage at which batteries are being floated (article 9622.62.4.).

3. **Monthly.** Clean batteries and grease the terminals with petrolatum as necessary. Examine battery connections and correct any faulty conditon such as breaks, frayed insulation, or grounds. Inspect for broken or cracked battery cases or jars. Give all batteries, except those which are charged from their own generator or are being floated, an equalizing charge. (See article 9622.45.) Take a complete set of voltage, temperature, and specific gravity readings on all batteries which have been given an equalizing charge.

4. **Quarterly.** Give all batteries which are charged from their own generator or are being floated, on equalizing charge. (See article 9622.45.) Take a complete set of voltage, temperature, and specific gravity readings on all batteries which have been given an equalizing charge.

5. **Semiannually.** Give each battery a test discharge (article 9622.62.2.).

6. A record of complete readings of cell voltages, temperatures and the specific gravity after equalizing charges needs to be kept only on those batteries for which tray records (NAVSHIPS 151) are required. NAVSHIPS 151 records are not necessary for portable batteries which are the sole power source for frequently used equipment, but should be kept up-to-date on emergency portable batteries which float on the line.

7. Where provided, Ships Maintenance Cards and records may be substituted for the above instructions if functional testing, as provided by the cards, is performed.

9622.94 SAFETY PRECAUTIONS

The following safety precautions shall be observed:

1. Keep flames and sparks of all kinds away from the vicinity of storage batteries.
2. Be sure to ventilate battery compartments which have been sealed, before entering the compartment, turning on any lights, making or breaking any electrical connections, or doing any work in the compartment.
3. Make sure ventilating apparatus of battery compartment is running properly before starting a charge.
4. Stop the charge if ventilation is interrupted, except in an emergency, and do not resume the charge until ventilation has been restored.
5. Charge a battery at the rates given on its name plate.
6. Never charge a battery at a higher finishing rate than that given on its name plate or in the table or article 9620.244.1.
7. When charging more than one battery at a time, make sure the voltage of the charging line exceeds the total voltage of the batteries being charged, and that the charging rate, in amperes, does not exceed the maximum charging rate of the battery having the lowest ampere-hour capacity in the line.
8. Lower the charging rate as soon as the battery begins to gas or the temperature reaches 125° F.
9. Keep the temperature of the battery compartment below 95° F. if at all possible.
10. Make no repairs to battery connections when current is flowing. Never connect or disconnect batteries on the charging line without first turning off the charging current.
11. When using tools about a battery be careful not to short circuit the battery terminals.
12. Always pour acid slowly into water and never water into acid. Guard skin and eyes against splaches of acid.
13. Exercise proper care in handling acid.
14. Do not add acid of greater specific gravity than 1.035 to a battery.
15. Do not store sulphuric acid in places where freezing temperatures are possible.
16. Keep the electrolyte level above the tops of separators.
17. Add only pure distilled water to a battery.
18. Do not, except in an emergency, discharge the battery below the given low-voltage limit.
19. Never allow a battery to stand in a completely discharged condition for more than 24 hours.
20. Do not operate the battery above 125° F.
21. All sparks should be avoided when removing or replacing batteries located in compartments which may contain gasoline fumes. Only tools with insulated handles should be used. Where batteries are used with one terminal grounded, the grounded terminal of the battery should be disconnected first when removing the battery and connected last when replacing the battery.
22. Never allow salt water to enter a battery cell, as chlorine gas, which is extremely toxic, will be evolved. Salt water should also not be used to wash out battery cases and jars. (See article 9622.106.)
23. Make sure all terminal connections are tight to preclude sparks due to loose connections.

9622.95 FUNCTIONAL TESTING PORTABLE STORAGE BATTERIES

1. A functional test is a method to determine if a battery is sufficiently operational to provide energy to satisfactorily operate specific equipment for a period of time. Test discharges are the most reliable means of determining a storage battery's condition. Functional testing may be done in lieu of a test discharge only when authorized by a Ships Maintenance Card.

2. Functional testing of Navy Type portable storage batteries for various shipboard applications vary with usage size, of battery and load. The test requirements are as follows:

a. Engine starting batteries. The batteries will be capable of starting an engine at least once a week.

b. Portable lantern batteries. The batteries will be capable of providing sufficient light for a period of one minute without any diminution of intensity and be tested at least once a week.

c. Gyrocompass batteries. The gyrocompass batteries will be functionally tested for a 20 minute period on battery power alone monthly.

d. Telephone batteries. Telephone batteries will be functionally tested during a peak load period for 4 hours on battery power, alone, monthly.

e. Functional testing of other portable storage battery service not covered above may be obtained upon request from the Naval Ships Engineering Center. This information will be required for new types of applications.

3. If the functional test fails, the battery shall be given an equalizing charge and retested. If the retest fails, the failed batteries shall be replaced.

Part 6. Repair

9622.101 BATTERIES CONTAINING SALT WATER

Batteries which have been immersed in the sea long enough for salt water to leak through the vent plugs are considered unfit for further service and should never be repaired.

9622.102 REPAIRS TO BATTERIES

1. Shipboard repairs should be performed only under the following conditions:

a. No replacement battery is readily available and the existing battery is capable of being repaired.

b. Minor repairs required, such as a small crack in the jar, terminal post or intercell connector, unsealed spots of sealing compound seal, specific gravity adjustment, or other repair which can be made quickly and readily aboard the using vessel.

2. Major repairs to batteries other than those specified in article 9622.101, including cleaning of sediment spaces and removal of moss on top of plates, shall be carried out only by authorized repair personnel at Naval shipyards, or other shore establishments, or on board repair ships and tenders. When repairs are necessary or desirable, a work request on a repair ship or a Naval shipyard shall be submitted. Unless a battery has been shown to be beyond economical repair, it shall be kept filled and charged. Repaired batteries shall always be returned in a fully charged condition. Battery repairs shall be handled as expeditiously as possible. Many batteries can be saved for future useful work if troubles are promptly detected and immediate steps taken to remedy them.

3. When using tools near a battery be careful to prevent a short circuit.

4. The repair methods described in articles 9622.103–9622.112 for battery repairs will be made on shipboard only when justifiable under article 9622.102.1.a.

9622.103 REMOVAL OF INTERCELL CONNECTORS

1. The intercell connectors may be removed from the battery in one of two ways, namely; by use of a connector puller, or by boring into the connector.

2. **Connector puller.** Remove the filling plug on the cell to be dismantled and place the puller in position. With the puller vertical, force the plunger down gradually until the connector is free from the post. The use of a connector puller renders the operation quick and easy, but necessitates trimming the posts before reassembly of the cell.

3. **Boring out the connectors.** Bore out the connector, using a brace and bit. The bit may be either a twist drill or a wood bit, preferably the latter, and should be at least as large as the post. Before boring, the bit must be accurately centered on the connector. The hole should be bored to a depth of about three-sixteenths inch. The vent plug should be in position while boring out to prevent lead chips from falling into the cell. When the hole has been bored to the proper depth, the connector will seem loose and the joint between the connector and post can be seen. After boring out the connector, insert a screw driver beneath the connector, and pry gently but firmly on the connector. Repeat this operation on the other side of the post and continue until the connector is free. Care must be taken to avoid damaging the cell cover and to avoid short circuiting the cell by allowing tools to come in contact with both posts at the same time.

9622.104 REMOVAL OF SEALING COMPOUND

Remove as much of the sealing compound as possible by means of a screw driver. The remaining compound may be removed with a putty knife, which is heated it necessary. Care should be taken that all compound is removed from the monobloc case or jar wall so as to prevent damage to the separators when pulling elements. Compound remaining on the cover can be removed after the element is out of the monobloc case or jar. Cell covers of batteries manufactured with polystyrene parts are cemented to the monobloc case or jar and have no sealing compound.

9622.105 REMOVAL AND REPLACEMENT OF ELEMENT

1. To remove the element grasp each post with a pair of pliers and pull vertically. Elements of batteries assembled in polystyrene cases or jars can not be removed.

2. **Protection of separators when removing.** In removing the element care should be taken not to damage the separators by striking the edges or bottom of the jar. When the element is clear of the monobloc case or jar, place it upside down with the posts or terminals resting on the bench.

3. After lifting the element pour the electrolyte carefully into a glass, lead, or rubber vessel. The electrolyte should not be poured out while the element is still in the monobloc case or jar as this will result in sediment becoming lodged between the plates, with consequent danger of later short circuits. If the electrolyte is to be used again, allow the sediment to settle as only clear electrolyte should be poured back into the cells.

4. While the element is still upside down, it may be inspected by slightly spreading the plates at the bottom, taking care that they are not spread so far as to strain or break a plate or a plate lug. The condition of the plates and separators may then be seen. Measure the depth of the sediment in the bottom of the monobloc case or jar. Then wash out the sediment and clean the inside of the monobloc case or jar thoroughly using fresh water. Do not use salt water to wash out the sediment, because salt water will react with sulphuric acid and sediment, which is essentially lead peroxide, to liberate chlorine gas.

5. When either the positive or negative plates require renewal, as evidenced by loss of active material, broken grids, excessive sulphation (hard, gritty negatives), the entire element consisting of both positive and negative groups shall be renewed. It should be noted that monobloc cases and jars are of standard dimensions, and it is therefore possible to replace elements of any type with elements available in standard stock.

9622.108 RENEWAL OF SEPARATORS

Prior to replacing the elements in the case or jar the separators should be examined to determine whether they are cracked or badly worn. If cracked, the separators should be replaced. If badly worn, the element should be replaced.

9622.109 DETACHING COVER FROM ELEMENT

Navy portable batteries are furnished with covers which are readily detachable from the elements. Generally, it is not necessary to detach the cover unless the element is to be replaced. To detach the cover of this type remove the sealing nut and then lift or pry the cover vertically. Some batteries may be furnished in which the cover is secured to the terminal posts of the element by lead burning the posts to lead bushings moulded into the covers. Such covers may be removed by drilling out the post in a manner similar to that used for removing the intercell connector. (Article 9622.103.3.) There are also some batteries in which the seal is made by the use of a soft rubber bushing around the post under the cover. The pressure of the bushing holds the post in place. However, the post may be withdrawn from the bushing by merely pulling it out. To replace the post a lubricant must be used, preferably rubber cement (Military Specification MIL-R-20091); if rubber cement is not available water may be used. In all cases, the intercell connector must be removed before the cover may be removed.

9622.110 REPLACING ELEMENT IN JAR

Before inserting elements in the monobloc cases or jars clean the inside edges of the containers and remove sealing compound from all the cover edges. Insert the element, seal the cover in place, refill with electrolyte from which all sediment has been removed, and replace the intercell connectors by lead burning.

9622.111 SEALING COVERS IN PLACE

1. The sealing compound used in sealing portable storage batteries is manufactured in accordance with Military Specification MIL-C-2687. This compound is required to furnish an acid-resistant and acid-tight seal between the cell cover and the case or jar at temperatures varying from 0° F. to 140° F. It is an inherent characteristic of sealing compounds to increase in cohesion and decrease in adhesion with decrease in temperature. At extremely low temperatures, therefore, a tendency may be shown to crack or break away from either the cover or the container, resulting in the loss of an acid-tight joint. Low melting point compounds always demonstrate better low temperature characteristics than higher melting point compounds. On the other hand, if surrounding temperatures approach or exceed the melting point of the compound used, rundown into the cell may be experienced and the seal is again lost. The selection of a suitable sealing compound is therefore a compromise, and the Navy Department specification for this material has been written on this basis. The melting point required is in excess of 150° F.

2. Localities in which considerable storage battery repair work is done should be provided with electrically heated, thermostatically controlled pots, adjusted to temperature between 350° F. and 375° F., for melting the compound prior to pouring. However, should a battery require resealing in an out-of-the-way place, sealing compound may be melted in almost any available receptacle such as a cooking utensil.

3. In pouring the compound, care should be exercised that no spaces exist between the cover and container that are large enough for the liquid compound to run through into the cell. Strips of higher melting point compound may be used to fill any such gaps. It is considered advantageous to pour compound in two steps as follows:

a. First pour should about half fill the sealing space and should be poured at a somewhat lower temperature than the final pour. It should be allowed "set" for about a minute.

b. Second pour should be at a slightly higher temperature and should complete the sealing. A gas flame run rapidly and carefully over the compound will smooth off any irregularities resulting from the pouring.

9620.112 BATTERY TO BE CHARGED AFTER REPAIRS

1. When the battery has been completely reassembled, give it an equalizing charge and adjust the gravity as necessary.

2. **Increasing specific gravity.** To increase the specific gravity in any cell, under the condition defined in article 9622.67.4. the following procedure shall be observed:

a. Give the affected cells a 4-hour equalizing charge, at the conclusion of which accurately determine the specific gravity, correcting if for electrolyte temperature existing at the time.

b. Withdraw electrolyte in an amount approximately equal to 1 percent of the total volume of electrolyte normally contained in the cell (article 9622.2) for each point that the actual specific gravity of the cell is below 1.215 specific gravity. For example, assume the specific gravity of the low cell is 1.195 specific gravity. The amount of electrolyte to be withdrawn would, therefore, be (1215 -1195) x 1 = 20 percent of the normal electrolyte volume of the cell. In no case, however, shall the electrolyte level be lowered below the tops of the separators by such withdrawal.

c. Restore the electrolyte level to normal by the addition of electrolyte of 1.300 gravity. The 1.300 gravity electrolyte should be added while the cells are on charge and gassing; this will ensure thorough mixing.

d. Charge affected cells at the finishing rate for a period of 1 hour, at the conclusion of which accurately determine the specific gravity, correcting it for electrolyte temperature existing at the time.

e. Repeat steps b., c. and d. as necessary to bring the specific gravity of the cell within the limits of 1.210 to 1.220 specific gravity at 80° F.

3. **Lowering specific gravity.** The specific gravity of any cell which is above the upper limit of 1.220 specific gravity (see art. 9622.67.3) may be reduced by following the procedure outlined in subparagraph 2. above, modified in the following particulars. The amount of electrolyte to be withdrawn should be approximately 1 percent of the total volume of that normally contained in the cell (art. 9622.2) for each 2 points that the specific gravity of the affected cell is above 1.215 specific gravity. After the withdrawal of electrolyte has been made, the level should be restored to normal by the addition of pure distilled water.

4. **Adjustment of specific gravity.** If it is desired to make more accurate calculations for the adjustment of specific gravity than can be done using the above approximation, the following formula should be used:

$$X = V \frac{(G_3 - G_1)}{(G_2 - G_1)}$$

Wherein:

X = volume of electrolyte at the initial specific gravity which is to be replaced by an equal amount of mixing electrolyte.

V = total volume of electrolyte in the cell, which is to remain constant.

G_1 = initial specific gravity of the electrolyte.

G_2= specific gravity of the mixing electrolyte, i.e., 1.300 specific gravity for raising, and 1.000 specific gravity for lowering specific gravity of the cell.

G_3= specific gravity desired.

5. In making adjustments of specific gravity, it must be borne in mind that the reference level for the new specific gravity is at the normal height of electrolyte in the cell.

Part 7. Laying Up Batteries

9622.121 STORAGE OF BATTERIES

1. There are two ways of laying up a battery; namely, dry and wet.

2. It is not considered advisable to store portable batteries for lengths of time requiring them to be placed in a dry condition. All batteries taken out of service that have 80 percent or more capacity should be maintained in a fully charged condition and issued at the first opportunity.

3. **Placing battery in wet storage.** If a battery is to be placed in wet storage, it should be first be given equalizing charge. Apply petrolatum to all exposed terminals. Store the battery in such a way that is rests on wooden strips so that there will be an air space all around the top and sides.

4. **Care of batteries in wet storage.** Batteries in wet storage shall be watered and be given an equalizing charge monthly, or more often if the specific gravity falls below 1.180. It is essential that these batteries be inspected at frequent regular intervals and the electrolyte level maintained above the tops of the separators. For battery trays for which records are kept (see article 9622.93), the battery-tray record should be kept up-to-date during such period of wet storage.

Part 8. Surveys of Batteries

9622.131 CAPACITY LIMIT BEFORE SURVEYING

It is the policy of NAVSHIPS to discard batteries when it has been definitely ascertained that they cannot be made to give more than 80 percent of their rated capacity. Since a battery may be only temporarily low in capacity, care must be exercised in determining its capacity during survey.

9622.132 PROCEDURE BEFORE SCRAPPING BATTERY

1. A battery shall not be scrapped unless it is definitely known that it cannot be made to give further useful service. On the other hand, care must be taken that time and money are not spent in the effort to keep in service batteries that should be scrapped. "A four year life is considered average for portable batteries which receive proper servicing."

2. When it is believed that a battery is not fit for further use, the following confirmatory procedure shall be used after first giving the battery an equalizing charge.

3. Discharge the battery at the 2-hour rate in accordance with the procedure in article 9622.64.7. Compute the capacity obtained and compare with rated capacity (article 9622.64.7.).

4. Batteries which deliver at least 80 percent of rated capacity on the test discharge and are otherwise in good condition should be recharged and restored to service.

5. Batteries which do not deliver at least 80 percent of rated capacity on the test discharge should be scrapped by the vessel or activity using the battery upon approval of the electrical officer.

6. A Battery which fails the functional test after an equalizing charge may be considered to be unsatisfactory for service and should be scrapped.

9622.133 SAVE MONOBLOC HARD RUBBER CASES

When portable batteries in monobloc hard rubber cases are surveyed, the elements may be scrapped but the cases should be cleaned and set aside in A. P. A. These cases are available for reissue, especially to tenders and repair ships, to be used either in replacing damaged cases or as parts of batteries to be assembled using elements from stock. The value of these cases is such that it would be economical to place contracts for portable storage batteries on the basis on monobloc cases being furnished by the government. This practice is possible when good, clean, used cases are allowed to accumulate and lots of 100 or so thus become available.

9622.134 INFORMATION REQUIRED ON SURVEY

On all requests for survey of portable batteries the following information shall be furnished for each tray to be surveyed:

1. Name of manufacturer.
2. Navy type and manufacturer's type.
3. Contract or order number under which purchased.
4. Date of initial charge.
5. Service for which used (boat, radio, etc).
6. Complete details of special treatments given to bring the capacity of battery (tray) to 80 percent or over.
7. Complete description of the condition of the battery at time of survey.
8. Comply with article 9622.57 (forwarding of tray record).

9622.135 COUNTER E. M. F. CELLS

Counter E. M. F. cells used in automatic telephone systems and elsewhere, which are identical in outward appearance to storage battery cells, should be surveyed only when the positive grids (plates) are practically destroyed. These cells normally have no active material on the plates, have no storage capacity, and will not take a charge.

Part 9. Alkaline Batteries

9922.137 TYPES

1. Types Nickel–cadmium (Ni–Cad), Silver–zinc (Sil–Zinc)

2. Service and Maintenance. For information on alkaline batteries refer to the BUREAU or NAVAL WEAPONS HANDBOOK: NAVWEPS 17-15 BAD-1.

Part 10. Dry Batteries

A. DEFINITIONS AND CHARACTERISTICS

9622.141 DRY BATTERY

1. A dry battery is made up of one or more dry cells which cannot be economically recharged after discharge. A dry cell is a unit source of direct-current electrical energy derived from chemical action. It is so designed that the

electrolyte is immobilized and will not leak regardless of the position of the cell. The cells are of the Leclanche, mercury, or low-temperature types.

2. Leclanche cells have a nominal open circuit voltage of 1.5 volts and are composed of:

a. A positive electrode which is an intimate mixture of manganese dioxide and powdered carbon in contact with a carbor rod or plate.

b. A negative electrode which may be a piece of sheet zinc, compressed zinc powder, or a zinc can.

c. Electrolyte which is a paste containing ammonium chloride (sal ammoniac), a small amount of zinc chloride and mercuric chloride, water, and wheat flour or starch.

d. Terminals, which may be of many types such as wire leads, Fahnestock clips, binding posts, sockets, flat caps, etc., depending on the use for which the battery is intended.

3. Mercury cells have a nominal open circuit voltage of 1.3 volts and are composed of:

a. A positive electrode, which is an intimate mixture of mercuric oxide and carbon.

b. A negative electrode of sheet zinc or compressed zinc powder.

c. Electrolyte, which is an aqueous solution of potassium hydroxide.

d. A steel container.

e. Terminals, which may be any of the types listed for Leclanche cells.

4. Low-temperature cells are made of the same materials as Leclanche cells, except that the electrolyte is modified to give better low-temperature (below zero Fahrenheit) performance. The positive electrode is made of highly active manganese dioxide, consequently low-temperature cells do not store as well as normal cells. Their use is not recommended unless they can be shipped, stored, and used at temperatures below 35° F.

9622.142 SPECIFICATION AND USE

1. Military dry batteries are covered by the coordinated Military Specification MIL-B-18B, Dry Batteries. This specification lists the type number, voltage, initial and delayed performance under a specified load, size, and weight of military dry batteries.

2. The fundamental use of a dry battery is as a source of electrical energy that can be conveniently transported, either while in use or prior to utilization, without the hazard of spilling corrosive material and the inconvenience of treatment before the energy is available.

9622.144 DRY BATTERIES NOT REVERSIBLE

Storage batteries are reversible since the active materials consumed during discharge are restored by passing a charging current through the battery. Dry batteries are not completely reversible. Experiments show that some additional capacity can be imparted to a dry battery by passing a charging current through it but the additional energy obtained is usually not sufficient to warrant the added cost of apparatus and problems of maintenance.

9622.145 CHEMICAL REACTIONS IN A DRY CELL

1. **Leclanche cells.**

a. The electrical energy is obtained from reactions between the zinc, sal ammoniac, and manganese dioxide as follows:

$$Zn + 2NH_4Cl + 2MnO_2 \rightarrow Zn(NH_3)_2Cl_2 + Mn_2O_3 + H_2O$$

Since manganese dioxide has a relatively high electrical resistance path to the carbon rod which serves as a conductor to carry the current out of the cell.

b. The current carrying material of the electrolyte paste is ammonium chloride (sal ammoniac). In addition, the paste contains some zinc chloride and a small amount of mercuric chloride. These reduce the local action that takes place in the cell when not in use. The water contained in the paste is an essential part of the electrolyte. A cell from which all water has been expelled by drying is useless. The term "dry battery" does not mean a battery in which water is absent, but merely one in which there is no free liquid electrolyte that may be spilled.

2. **Mercury cells.** The electrical energy is obtained from the reduction of mercuric oxide to metallic mercury and the oxidation of zinc to zinc oxide as indicated by the following:

$$HgO + Zn \rightarrow ZnO + Hg$$

The carbon of the positive electrode and the electrolyte do not enter into the reaction, but act as conductors to carry the current through the cell.

3. **Low-temperature cells.** The chemical reaction resembles the reaction in Leclanche cells in that metallic zinc is converted to a chloride or hydroxide and the manganese dioxide is converted to a lower oxide of manganese.

9622.146 CELL SIZES

Dry cells come in a wide variety of sizes and shapes. The most commonly used Leclanche and low-temperature cells are cylindrical in shape with the dimensions given in the following table.

9622.147 CHARACTERISTICS OF LECLANCHE CELLS

1. **Equivalent ohms per cell.** One way of measuring the performance of a single dry cell is to connect it to a fixed external resistor and allow it to discharge continuously. The length of time the discharge continues before the terminal voltage drops to a specified value is one measure of the cell's performance. The concept of equivalent ohms per cell is needed to apply the same scheme to a battery made up of a number of cells connected in series, parallel, or series-parallel. Suppose that N_1 cells are connected in series and that N_2 rows of N_1 cells are connected in parallel. The equivalent ohms per cell is given by:

$$Re = R\frac{N_2}{N_1}$$

where:

Re = equivalent ohms per cell
R = fixed external resistance connected to the battery terminals
N_1 = number of cells connected in series
N_2 = number of rows connected in parallel

A little consideration will show that the load on each cell in the battery (assuming that all cells act alike) is just the same as if there were a single cell with the equivalent ohms per cell connected to its terminals.

2. **Discharge at 70° F.** Figures 9622-14 a. to g. show the discharge characteristics at 70° F. for the most commonly

Sizes of the most commonly used Leclanche and low-temperature cells.

DIMENSIONS IN INCHES

Size	Diameter*	Height*
AA	17/32	1-7/8
A	5/8	1-7/8
B	3/4	2-1/8
C	15/16	1-13/16
D	1-1/4	2-1/4
F	1-1/4	3-7/16
No. 6	2-1/2	6

*Approximate can dims. Height over terminals will be somewhat greater.

used sizes of Leclanche cells. These figures can be used to estimate the average performance of fresh batteries, namely, batteries less than 3 months old which have not been subjected to conditions of unusually high temperature or low humidity in storage. To use these figures, first compute the equivalent ohms per cell of the particular application in which the cells are used, then refer to the appropriate figure for the length of time the cells can be expected to discharge continuously before the voltage falls to a specified end value. For example, figure 9622-14 f. shows that a size F Leclanche cell will discharge continously through 5 ohms/cell for 2.2 hours before the voltage falls to 1.25 volts per cell. Times to other voltages are:

Voltage	Time (hours)
1.2	3.8
1.1	6.8
1.0	10.0
0.9	12.5

For 10 ohms/cell, the times to different voltages are:

Voltage	Times (hours)
1.25	11.5
1.20	17.0
1.10	23.0
1.00	28.0
0.90	35.0

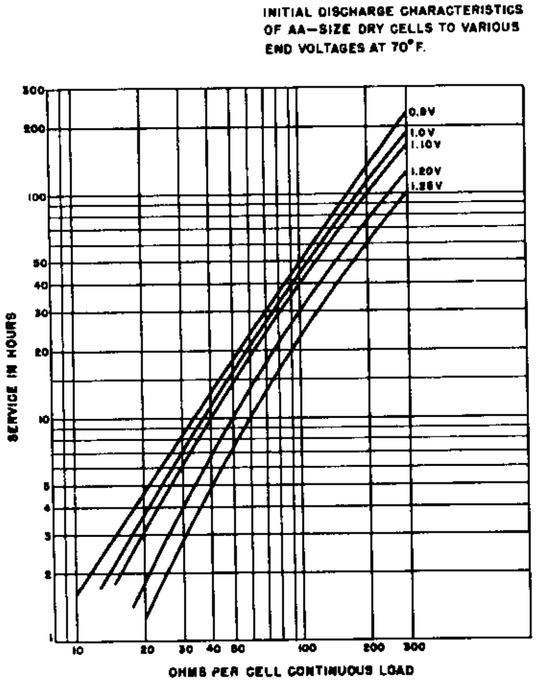


Figure 9622-14 (a). Initial discharge characteristics of size AA Leclanche cell at 70° F.

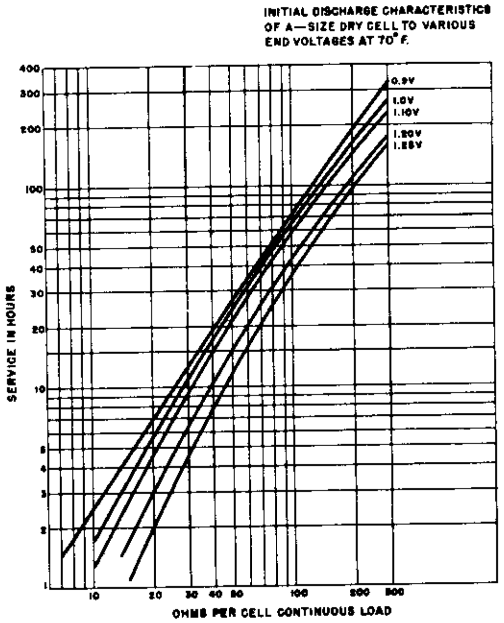


Figure 9622-14 (b) Initial discharge characteristics of size A Leclanche cell at 70° F.

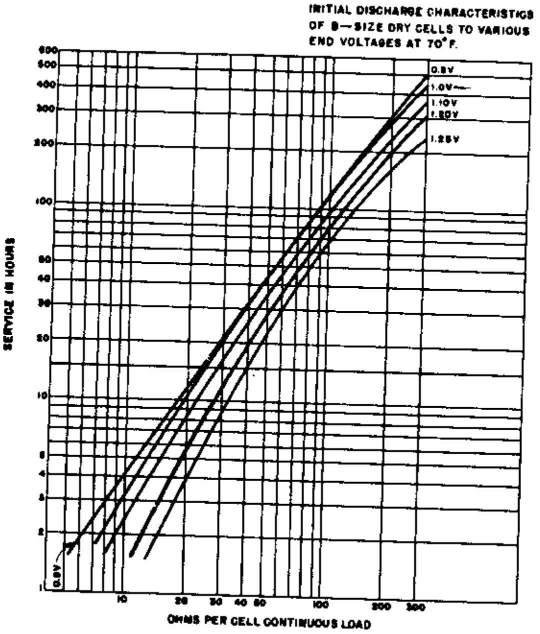


Figure 9622-14 (c). Initial discharge characteristics of size B Leclanche cell at 70° F.

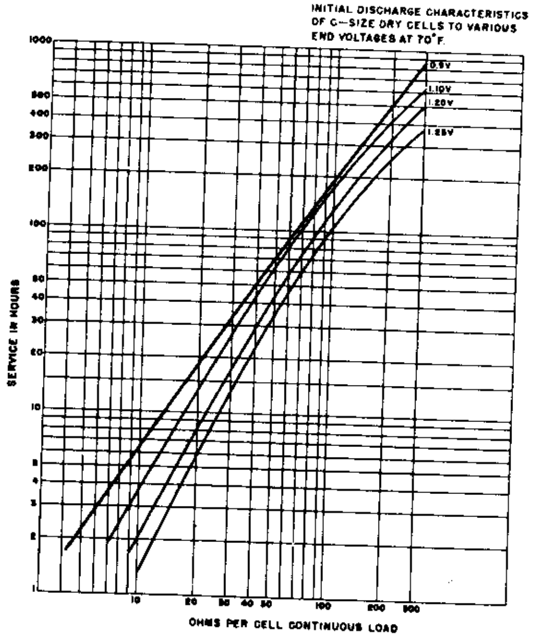


Figure 9622-14 (d). Initial discharge characteristics of size C Leclanche cell at 70° F.

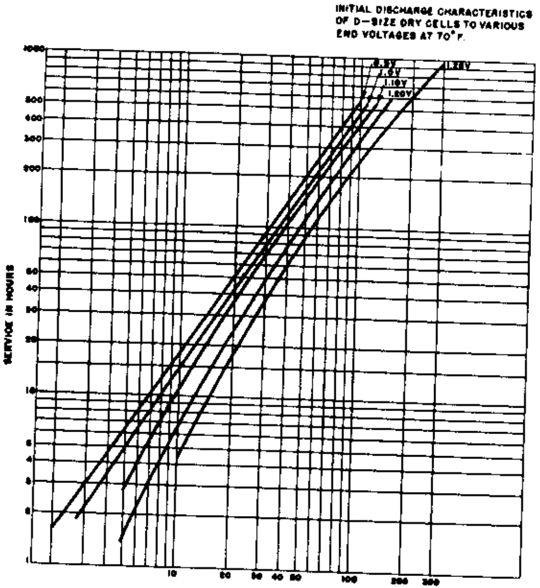


Figure 9622-14 (e). Initial discharge characteristics of size D Leclanche cell at 70° F.

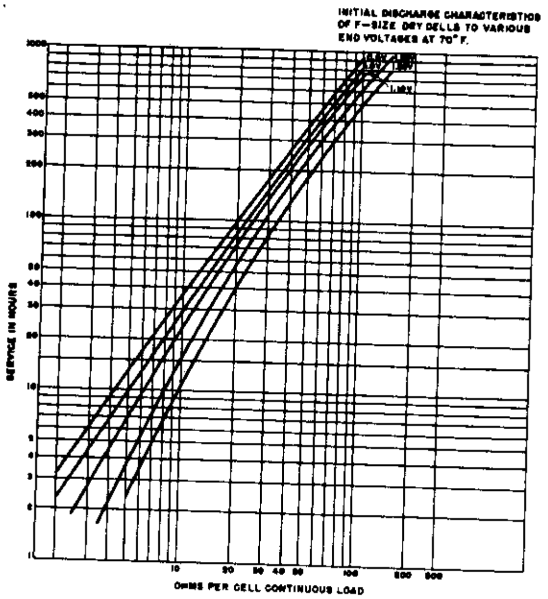


Figure 9622-14 (f). Initial discharge characteristics of size F Leclanche cell at 70° F.

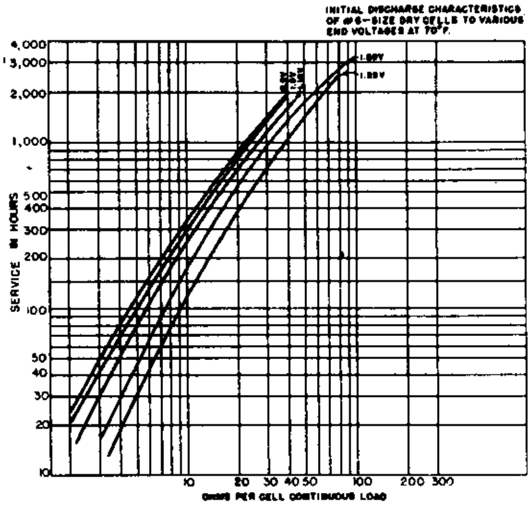


Figure 9622-14 (g). Initial discharge characteristic of size No. 6 Leclanche cell at 70° F.

3. **Effect of intermittent discharge.** Dry batteries have the property of recuperation. If a battery which has apparently been exhausted is allowed to stand on open circuit for a time, polarization products are consumed, the battery recuperates, and is capable of being further discharged. If we measure capacity by the total time of discharge through a specified ohms per cell to a specified end voltage, the capacity is greater for an intermittend discharge than for a continuous discharge. Figure 9622-15 gives information on the greater capacity which can be obtained from a size F Leclanche cell by discharging it intermittently instead of continuously.

4. **Effect of temperature.** The capacity of a Leclanche dry battery, as measured by time of discharge through a specified ohms per cell to a specified end voltage, increases with the temperature. This is shown by figure 9622-16 which is for a size F Leclanche cell discharged through 83.3 ohms to 1 volt.

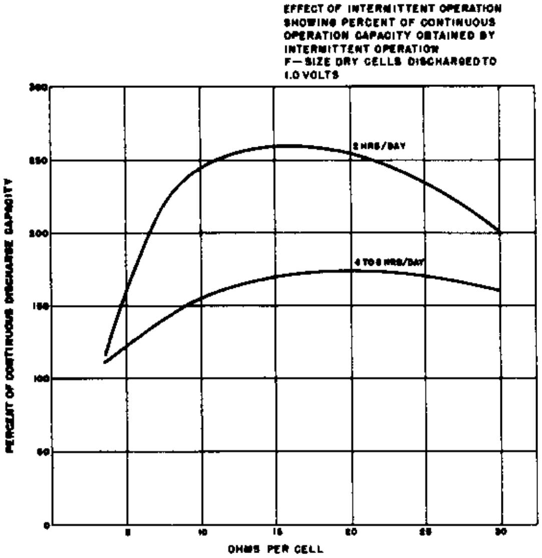


Figure 9622-15. Effect of intermittent operation showing percent of continuous duty capacity obtained by intermittent operation.

9622.148 CHARACTERISTICS OF OTHER CELLS

1. **Mercury cells.** The high capacity to volume ratio results in 2 to 15 times the capacity of Leclanche cells of the same volume (or proportionally reduce the volume for the same capacity). These batteries maintain a relatively constant voltage of 1.2 to 1.3 volts throughout most of the useful life and are useful as reference sources in regulated power supplies. These cells are not used as extensively as Leclanche cells because of their greater cost.

2. **Alkaline-manganese dioxide cells.** Cold Weather operation at-40°F will reduce the capacity of these cells to approximately 9% of the 70°F capacity, whereas the Leclanche cells are inoperative at -10°F. At 70°F this battery provides about double the capacity requirement for the standard Leclanche cell of similar volume. These cells have a greater cost than Leclanche cells.

3. **Magnesium cells.** A magnesium anode battery offers advantageous characteristics over the Leclanche battery for use in high temperature areas, especially in extended shelf life.

B. SHIPMENT AND STORAGE

9622.161 UNIT PACKAGES

All batteries and materials used in their construction are carefully inspected by government inspectors to make sure they are in conformity with specifications. Specifications require batteries to be wrapped in small unit packages con-

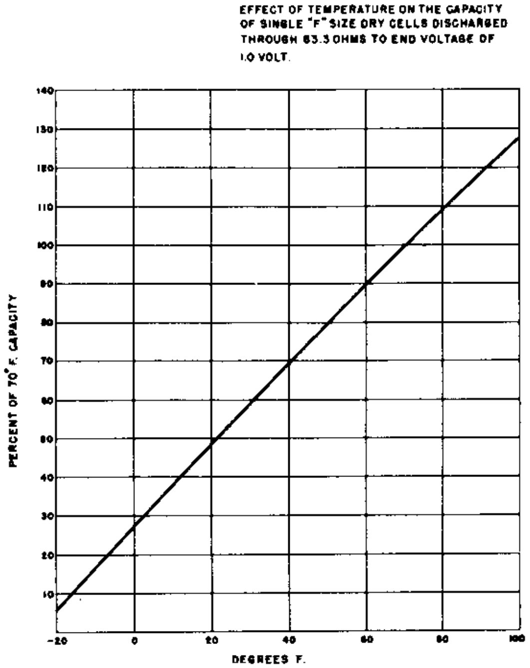


Figure 9622-16. Effect of temperature on capacity of size F Leclanche cell discharged continuously through 83.3 ohms to a final voltage of 1.0 volt.

taining one or more batteries. The unit packages are wrapped in polyethylene plastic bags. **The polyethylene bags on the unit packages should not be removed until the batteries are needed for actual use.** This wrapping helps to protect the batteries from the detrimental action of outside temperature and humidity. The unit packages are packed in intermediate packages which are made of corrugated carboard and are packed in wooden shipping containers.

9622.162 PACKING OF 19026 BATTERIES

The Navy Type 19026 dry battery is the only exception to the packaging procedure. Because of its large size, it is always delivered to store activities packed in wooden boxes suitable for export shipment and should be kept in this packing box until issued for service.

9622.163 STORAGE

Dry batteries are perishable. They deteriorate even when not in use, so that care should be exercised to provide storage conditions which will minimize deterioration. Where possible, dry batteries should be stored at temperatures equal to or less than 35° F. in a room which is not dehumidified. Where refrigeration is not available, dry batteries should be stored in the coolest available space where they are not subjected to excessive dampness or large temperature fluctuations. Any battery taken from refrigerated storage should be allowed to warm up to between 65° F. and 80° F. before use in order to obtain maximum capacity.

9622.164 SHELF LIFE

1. **Definition.** The Navy defines shelf life as the length of storage time beyond which a group of batteries will contain so many dead batteries that the group is not considered fit for use. Shelf life depends not only upon the kind and size of a cell, but also upon the intended application. If a specific use requires that a high percentage of a battery's initial capacity be available and that the voltage drop on discharge be small, the shelf life assigned to a group of batteries intended for this application will be less than for a use which needs less capacity retention and can tolerate a greater voltage drop during discharge.

2. **Effect of size on shelf life.** Batteries containing the smaller cell sizes do not retain capacity as well as those which contain the larger cell sizes. The following table gives the approximate percent of initial capacity retained after 1 and 2 years by several sizes of Leclanche cells. These figures are for batteries stored at room temperature. The table is arranged in order of increasing cell size from left to right and top to bottom.

Percent Initial Capacity Retained After Storage

Cell size	1 year	2 years
AA, A, B, C	70-80	50-60
D, F, 6	85-90	75

3. **Shelf life tables.** Shelf life tables are issued by the various supply offices. Present shelf life tables are derived on the basis of general use requirements and will give a longer shelf life than may be tolerable for critical applications.

4. **Test of individual batteries.** It should be clear from the definition of shelf life that the assignment of a certain shelf life to a given type of battery does not mean that each indidual battery of this type will be good as long as it has not reached the end of its shelf life. It means only then in a group of these batteries a substantial percentage will be good so long as the end of the shelf life is not reached. The determination of whether an individual battery is usable or not can best be made by placing it in the equipment which it is supposed to operate and seeing whether it works or not. It this is not convenient, the battery can be tested by connecting it to a load equivalent to that of the equipment and measuring the closed circuit battery voltage. If this is above that required for satisfactory equipment operation, the battery is fit for use. No inference as to the hours of use left in the battery can be drawn from either of these tests or from any other nondestructive tests now available.

5. **Survey.** Batteries which have reached the end of their shelf life should be surveyed.

9622.165 EQUIPMENT USING DRY BATTERIES

1. Dry batteries should not be shipped or stored in the equipment with which they are to be used. The reasons are:

    a. Dry batteries deteriorate in storage. Putting fresh batteries in the equipment as near as possible to the time of use gives the only assurance of reliable operation.

    b. Dry batteries shipped or stored in equipment may become discharged either by internal chemical reaction or by leakage currents across normally open contacts. As a result, water is generated in the cells and electrolyte may leake out and corrode the equipment.

2. When the batteries in an equipment are no longer capable of operating it, they should be removed immediately to avoid damage to the equipment from electrolyte leakage.

9622.166 ISSUING DRY BATTERIES

1. There is no reliable nondestructive test which will show the amount of capacity remaining in a battery after it has been stored for a considerable length of time or partially discharged. For this reason, the discretion of the issuing officer is an important factor in issuing batteries.

2. It is usually desirable to issue the oldest stock first. This is satisfactory when the batteries are to be used close to the warehouse and can be replaced readily. However, if batteries are to be used in a remote locality where premature failure may cause serious inconvenience, it is recommended that only batteries less than 6 months old be issued. The specifications require all batteries to be marked with the date of manufacture in order to show their age. The date of manufacture is given by a coded three digit number. The first two numbers represent the month the batteries were made, the third the year of the decade in which they were made. For example, 043 means the battery was made in April 1953, or 04 for April and 3 for 1953.

3. Batteries which have been subjected to extraordinary heat or humidity should never be issued except in an emergency.

C. SERVICE AND OPERATION

9622.171 PUTTING DRY BATTERIES IN SERVICE

One of the main advantages of dry batteries is the ease with which they are put in service. All that is required is to place the battery in its operating position and connect it to the apparatus to be operated. Batteries with wire leads are connected after removing the waterproof tape covering the ends of the wires. In some cases the insulation on the wire leads may be extended all the way to their ends. In this case the wires must be bared, but care should be taken not to cut or scratch the wire, as this will make it liable to break. In placing batteries with socket connections in service, it is necessary to remove the protective covering on the socket. Care must be taken not to short circuit the battery across any of the socket terminals.

9622.172 PRECAUTIONS

The limited attention necessary for the operation of dry batteries is one of the factors which causes them to be used so extensively. The only precautions necessary are:

1. Avoid exposing the battery to high temperatures or extremes of high or low humidity for a long period of time and;
2. Avoid short circuiting the connections of the battery.

9622.173 LAYING UP

If it is expected that dry-battery operated equipment is to be idle for 2 weeks or longer, the dry batteries should be removed from the equipment. Batteries that are comparatively fresh, that is, used only a short time, may be turned into store with a record of approximate amount of use. Batteries that have been used quite extensively should be removed and scrapped. When the amount of service given by a battery is not known, it is best to remove it and if replacement stock is readily available, scrap it. Where stock is not readily available, it may be possible to save the battery and use it when the equipment is returned to service. In this case the battery should be removed from the equipment and stored, preferably under conditions approaching as nearly as possible those described in article 9622.163. If dry batteries are left in equipment while it is idle, there is a possibility that rupture of the battery may cause electrolyte to leak out of the battery and corrode the equipment. In addition, the battery may expand, making its removal difficult.

9622.174 SAFETY PRECAUTIONS

The following safety precautions should be observed:

1. Care should be taken to store dry batteries in conditions as outlined in articles 9622.151–9622.153 inclusive and to keep them from exposure to heat, extremes of high or low humidity, and water.
2. The 300-volt B section of the Navy type 19026 pack battery is capable of imparting a very serious, if not fatal, shock to anyone coming in contact with it. Therefore, great care should be taken not to come in contact with the terminals of this battery, or of any other high voltage battery.
3. When equipment operated by dry batteries is to remain idle for more than 2 weeks, the batteries should be removed and then either scrapped or stored.
4. When disconnecting the Navy type 19026 battery from the operating apparatus, the current flow should be stopped before disconnecting the plug. It is possible for sufficient gaseous hydrogen to accumulate in this battery to produce a serious explosion if ignited. A spark produced by pulling the plug from the socket while current is flowing is liable to ignite this gas.
5. Wire lead terminals should be kept insulated when the battery is not connected to apparatus in order to prevent a short circuit. This could result in sufficient heat to cause a fire. In addition, a discharge caused by a short circuit generally produces so much water within the cells that they burst, spilling corrosive electrolyte which can damage furniture and equipment.
6. Never continue to use a multicell dry battery after its closed circuit voltage has dropped below a value equal to 0.9 volts per cell. Discharging a battery beyond this point will force current through some cells of the battery which may be completely discharged. This results in the generation of hydrogen and oxygen gas due to electrolysis of water. When this happens, there is danger of hydrogen explosion and damage to personnel and equipment.
7. Mercury-cell batteries may explode if improperly used. To prevent this form occurring, the following additional precautions must be followed:

    a. Never discharge a mercury-cell battery after the battery fails to operate the equipment or the voltage falls below 0.9 volts per cell.

    b. Never leave the battery switch "on" when the equipment is not in use or after the battery fails to operate the equipment.

    c. Never impose a "dead short circuit" on a mercury cell or allow to become overheated. A temperature of about 400° F. is sufficient to cause a mercury cell to explode.

    d. Mercury-cell batteries having reached the end of their shelf-life in storage should never be issued to using activities.

    e. Discard exhausted mercury-cell batteries as soon as possible. Dead single and multicell mercury batteries with steel jackets should have holes punched in the jackets before being discarded to release any gas which might have formed.

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